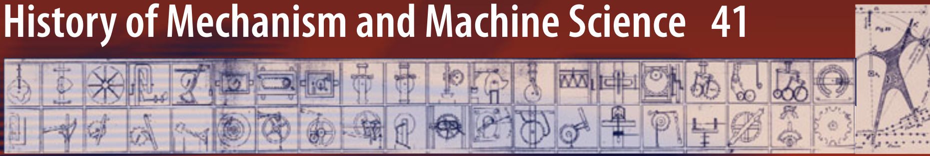
History of Mechanism and Machine Science 41



Marco Ceccarelli
Alessandro Gasparetto *Editors*

# Distinguished Figures in Mechanism and Machine Science

## Legacy and Contribution of the IFToMM Community, Part 5

Springer

# History of Mechanism and Machine Science

Volume 41

This bookseries establishes a well-defined forum for Monographs and Proceedings on the History of Mechanism and Machine Science (MMS). The series publishes works that give an overview of the historical developments, from the earliest times up to and including the recent past, of MMS in all its technical aspects.

This technical approach is an essential characteristic of the series. By discussing technical details and formulations and even reformulating those in terms of modern formalisms the possibility is created not only to track the historical technical developments but also to use past experiences in technical teaching and research today. In order to do so, the emphasis must be on technical aspects rather than a purely historical focus, although the latter has its place too.

Furthermore, the series will consider the republication of out-of-print older works with English translation and comments.

The book series is intended to collect technical views on historical developments of the broad field of MMS in a unique frame that can be seen in its totality as an Encyclopaedia of the History of MMS but with the additional purpose of archiving and teaching the History of MMS. Therefore. the book series is intended not only for researchers of the History of Engineering but also for professionals and students who are interested in obtaining a clear perspective of the past for their future technical works. The books will be written in general by engineers but not only for engineers. The series is promoted under the auspices of International Federation for the Promotion of Mechanism and Machine Science (IFToMM).

Prospective authors and editors can contact Mr. Pierpaolo Riva (publishing editor, Springer) at: pierpaolo.riva@springer.com

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Marco Ceccarelli · Alessandro Gasparetto
Editors

# Distinguished Figures in Mechanism and Machine Science

## Legacy and Contribution of the IFToMM Community, Part 5

Springer

*Editors*
Marco Ceccarelli
Department of Industrial Engineering
University of Rome Tor Vergata
Rome, Italy

Alessandro Gasparetto
DPIA
University of Udine
Udine, Italy

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# Preface

This is the fifth volume of a series of books whose aim is to collect contributed papers on figures in Mechanism and Machine Science (MMS). The last volume follows four ones with the first published in 2007, with content that is specifically focused on eminent figures in the IFToMM community in the International Federation for the Promotion of MMS in its last 50 years of activities.

The five volumes represent a project of a dictionary of who-is-who in MMS with the encyclopedic character of the whole book series by emphasizing the significance of MMS through time. The uniting characteristic of the volumes is that the papers all recognize persons whose scientific work resulted in relevant technical-scientific achievements with impacts in technology and science in the historical evolution of the fields of MMS not only within IFToMM as well as with an influence in society development. Biographical notes describing the efforts and experiences of these persons are included as well, but a technical survey is the core of each contributed paper.

This is the fifth volume of a series of edited books that started in 2007 with the aim to collect contributed papers on distinguished figures in (Mechanism and Machine Science (MMS). This is a continuation of the first volume that was published in 2007 (ISBN 978-1-402-06365-7), the second one in 2010 (ISBN 978-9-048-12345-2), the third one in 2014 (ISBN 978-9-401-78946-2), and the fourth one in 2020 (ISSN 1875-3442), all combining ancient and recent scholars in order not only to give an encyclopaedical character to this project but also to emphasize the significance of MMS over time.

This fifth volume of the series project has been possible, thanks to the invited authors, who have enthusiastically shared this initiative and spent time and efforts in preparing the chapters in due time. The stand-alone chapters cover the wide field of the History of Mechanical Engineering with a specific focus on MMS and IFToMM by specific discussions of the distinguished figures and their specific activities they have carried out during their lives with impacts also in the next developments with also today fame. In this book, special attention is addressed to distinguished figures who gave contributions to the history of IFToMM, the International Federation for the Promotion of MMS, and also with their activity in the fields of MMS. The aim is to record and give merit to those IFToMMist figures who may not yet be well known in the international community, also with the aim to show that the science and technology evolution and particularly the History of IFToMM is built day by day even with very recent contributions that need to be recognized as soon as possible not only for the historical credits but for tracking the future and for attracting more work and attention to those topics and association aggregation.

We believe that readers will take advantage of each of the chapters in this book and future ones by getting further satisfaction and motivation for her or his work (historical or not).

We also wish to acknowledge the professional assistance of the staff of Springer Science+Business Media and especially Mr. Pierpaolo Riva, the Springer Editor of the book series, who has enthusiastically supported this project with his help and advice in the preparation of the fifth volume.

We are grateful to our families and friends and colleagues for their patience and understanding, which have made it possible for us to work on this book and the book-series project of distinguished figures on MMS.

Rome, Italy
Udine, Italy
August 2022

Marco Ceccarelli
Alessandro Gasparetto

# Contents

# About the Editors

**Marco Ceccarelli** (Rome, May 26, 1958) received his Ph.D. in Mechanical Engineering from La Sapienza University of Rome, Italy, in 1988. He is Professor of Mechanics of Machines at the University of Rome Tor Vergata, Italy, where he chairs LARM2: Laboratory of Robot Mechatronics. His research interests cover subjects of robot design, mechanism kinematics, experimental mechanics with special attention to parallel kinematics machines, service robotic devices, mechanism design, and history of machines and mechanisms whose expertise is documented by several published papers in the fields of Robotics and Mechanical Engineering. He has been visiting professor in several universities in the world. He is an ASME fellow. Professor Ceccarelli serves in several Journal editorial boards and conference scientific committees. He is editor-in-chief of the MDPI journal Robotics and of the SAGE International Journal on Advanced Robotic Systems for the area on Service Robotics. He is editor of the Springer book series on Mechanism and Machine Science (MMS) and History of MMS. He has been the President of IFToMM, the International Federation for the Promotion of MMS in 2008–11 and 2016–19. He has started several IFToMM sponsored conferences including (HMM) Symposium on History of Machines and Mechanisms, MEDER (Mechanism Design for Robotics), and MUSME (Multibody Systems and Mechatronics). More information is available on the web page: LARM2 webpage: https://larm2.ing.uniroma2.it/.

**Alessandro Gasparetto** (Rovigo, October 26, 1968) received his M.Sc. in Electronic Engineering from the University of Padova, Italy, in 1992; M.Sc. in Mathematics from University of Padova, Italy, in 2003; Ph.D. in Mechanics of Machines from University of Brescia, Italy, in 1996. He is Full Professor of Mechanics of Machines at the Polytechnic Department of Engineering and Architecture, University of Udine (Udine, Italy), where he is the head of the research group in Mechatronics and Robotics, as well as the Head of the Department (since 2021). He has been included in the ranking of the top 2% most quoted and authoritative scientists in the world, published by researchers at Stanford University (2019 and 2021). Since 2017, he is the Chair of IFToMM Italy, the Italian branch of IFToMM (the International Federation for the Promotion of Mechanism and Machine Science). Since 2018, he is the Chair of the IFToMM Permanent Commission for the History of Mechanism and Machine Science. His research interests are in the fields of modeling and control of mechatronic systems, robotics, mechanical design, industrial automation, and mechanical vibrations. He is the author of more than 200 international publications, and has been involved in the scientific and organizing committees of several conferences, as well as in many research projects, at the regional, national, and European level.

# Andrew D. Dimarogonas (1938–2000)

**Thomas G. Chondros and Sofia D. Panteliou**

**Abstract** Professor Andrew D. Dimarogonas (1938–2000) was widely recognized as a distinguished authority in various specialties of mechanical engineering. He made important contributions to the mechanical design, vibrations and the history of engineering and technology. His last appointment was as W. Palm Professor of Mechanical Design and the Director of the Manufacturing Program in the School of Engineering and Applied Science at Washington University, St. Louis, MO. Professor of the University of Patras from 1974 to 1986 was the founder of the Design and Dynamics Division in the Mechanical Engineering Department, also the founder of the Greek IFToMM National Committee. He received the 1999 ASME Engineer-Historian Award for his many works on integrating the history of mechanical engineering. His books on computer-aided machine design and vibration for engineers won him international acclaim as a leading expert in the field of mechanical design. This work provides an outline of Prof. Dimarogonas' contribution in the Science of Engineering, the Design Theory, Vibration Engineering, Ethics in Engineering, the History of Technology, and the IFToMM.

## 1 Biographical Notes

### *1.1 Life and Career*

Professor Andrew D. Dimarogonas (1938–2000) was born in Piraeus, Greece. Professor at the University of Patras (UP) from 1974 to 1986, he was the founder of the Design and Dynamics Division in the Mechanical Engineering Department, also

T. G. Chondros (✉) · S. D. Panteliou
University of Patras, 265 00 Patras, Greece
e-mail: chondros@upatras.gr

S. D. Panteliou
e-mail: panteliou@upatras.gr

 
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the founder of the Greek IFToMM National Committee. He made important contributions to the Mechanical Design and Vibrations, the Theory of Machines, and Engineering Education. His last appointment was as W. Palm Professor of Mechanical Design and the Director of the Manufacturing Program in the School of Engineering and Applied Science at Washington University in St. Louis, Missouri. Andrew Demos Dimarogonas received the Mechanical and Electrical Engineering degree from the Athens National University of Technology (NTUA) in 1961 having been awarded a national scholarship. Between 1956 and 1961 he was a union and political activist, elected to leadership positions in local and national student unions and the Youth Division of the United Democratic Left party (EDA).

He served in the Greek Army (1961–62) in the Technical Corps and was honorably discharged. After Army Service, he worked in the Industry as design engineer, and the Public Power Corporation (PPC) of Greece as distribution network design engineer, 1962–67. At the same period he was a Lecturer at the NTUA. In 1964 he married Catherine, his college-years sweetheart since 1957, who survives him with their two sons: James (Demos), Mechanical Engineer (Ph.D.) and Peter (Panagiotis) Mechanical and Automotive Engineer.

In 1967 he was dismissed from the PPC and the NTUA by the C and IZ Decrees of the military junta, together with many other democrats faculty members or government employees as a threat to the "social establishment" of the dictatorship. This event triggered his decision to immigrate to the United States in 1967. Prof. Dimarogonas in the 90s is shown in Fig. 1.

In the US, A. D. Dimarogonas worked for the Turbine Department of the General Electric Company as design engineer and later was promoted to Technical Leader for dynamics and Technical Leader for mechanical development of the Large Steam Turbine Generation Division, Schenectady, New York, 1967–1972. Supervised a team of 8–12 engineers in Large (600–1350 MW) Turbomachinery Research and Development with annual budget 1–3 million US $. He consulted in the manufacturing sector from that time, dealing with such diverse products as balancing machinery, automotive fuel pumps, intelligent equipment design and non-destructive

**Fig. 1** Andrew D. Dimarogonas (1938–2000)

testing, industrial automation, engine rotor dynamics. In parallel, he was a graduate student at the Rensselaer Polytechnic Institute (RPI) (1968–70), was awarded a Ph.D. in Mechanical Engineering (ME) in 1970 and was appointed adjunct Assistant Professor of ME there (1970–72).

In 1972 he was appointed Associate Professor of Mechanical Engineering at Lehigh University, Bethlehem, Pennsylvania. While at Lehigh University, one of Dimarogonas' many accomplishments was the application of computer modelling and simulation to the design of a 500-ton railroad car, the largest in the world at that time.

In 1974, the junta in Greece fell and A. D. Dimarogonas was reinstated to the NTUA and PPC retroactively. He was then elected Chaired Professor of Machine Design at the University of Patras (UP) in Greece and subsequently was elected by the faculty as Director of the Design Division, Chairman of the Mechanical Engineering Department, and Dean of the School of Engineering (1974–83).

Prof. A. D. Dimarogonas was the founder of the Design and Manufacturing Section of the Mechanical Engineering Department of the University of Patras. He taught a variety of courses to both, the newly founded in 1972, Mechanical Engineering Department and the Civil Engineering Department. Courses taught include among others: Strength of Materials, Machine Design, Machine Elements and Numerical Methods for Engineers, Vibration for Engineers, Analysis and Synthesis of Mechanisms, and the History of Engineering.

In 1982 Prof. Dimarogonas protested against the Socialist Government University Reform Bill (for giving control of the universities to political parties) and stepped down from university administration. Later, he took a sabbatical leave from the UP to become general technical manager of the steel manufacturing company Metallourgiki-Halyps, a Höesch affiliate (1983–85), supervising 800 professional and technical employees involved in production, renovation, and computer integration of the steel mill producing 4 million ton per year, annual budget $ 80 million. The five million $ project was implemented with the Japanese Engineering Company, Nikko Industries. He also was member of the Company Board, and continued until 1986 as a consultant.

In 1986 he returned to the USA and was appointed W. Palm Professor of Mechanical Design. The William Palm Professorship was established on February 24, 1879 by the president and founder of Washington University in St. Louis, William Greenleaf Eliot. The $50,000 endowment from the estate of William Palm, a German immigrant who came to St. Louis in 1804 shortly after graduating from the University of Berlin, a prominent St. Louis businessman and close friend of many of the original members of Washington University's Board of Directors. Palm formed the Palm and Robertson company, which built locomotives, one of the first such businesses in St. Louis. The first holder of this prestigious appointment was Charles A. Smith, who held the W. Palm Professorship appointment from 1880 to 1883. Since that time, only three other engineers had been offered the William Palm Professorship. John1 B. Johnson held the appointment from 1884–1900; John Lan Van Ornum held it from 1900–1934; and Ernest Osgood Sweetser held it from 1947 to 1951. On November 11, 1986 Andrew D. Dimarogonas, was appointed W. Palm professor of mechanical design. At the dinner held at Washington University's Whittemore House, after being introduced to the audience by the Dean of the School of Engineering and Applied Science, James M. McKelvey, and the Chairman of the Department of Mechanical Engineering, Salvatore P. Sutera, Dimarogonas presented his views on the importance of machine design in a talk entitled: *The Beauty of the Machine*. The appointment of Dimarogonas as William Palm Professor greatly strengthened the Department of Mechanical Engineering and added to the overall excellence of Washington University's School of Engineering and Applied Science.

He was a Fellow of ASME, the American Society of Mechanical Engineers, Society of Naval Architects and Marine Engineers, the Society of Design and Process Science, and American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE), a Professional Engineer in the State of New York and Greece. He was a member of the Technical Chamber of Greece and the Hellenic Society of Mechanical and Electrical Engineers. He served as national trustee of the Greek Council of Peace, member of the governing board of the Technical Chamber of Greece and chairman of the Mechanical Engineering Accreditation Board. In 1977 he ran (unsuccessfully) for the Greek Parliament in the Patras district.

He authored over 20 books, more than 150 research papers and six patents. A selection of his published work in the References section is organized as follows: Dissertation, Books, Patents, Major Addresses, and selected papers in the areas of Engineering Education and History of Technology (Dimarogonas 1976b, 1978b, 1982, 1984b, 1990c, d, 1992c, d, e, 1994c, 1995a, b, c, 1993b, c, d, e, 1997c; Dimarogonas and Chondros 1997), Friction and Wear (Theophanopoulos and Dimarogonas 1967; Dimarogonas 1969, 1973e, f; Masouros et al. 1977, 1979; Dimarogonas and Massouros 1979a; Dimarogonas and Michalopoulos 1981; Michalopoulos and Dimarogonas 1981, 1982; Massouros and Dimarogonas 1986; Michalopoulos et al. 1986; Andritsos and Dimarogonas 1986; Dimarogonas 1987c, 1988c; Dimarogonas and Kollias 1989, 1992b; Kollias and Dimarogonas 1993a, b; Anifantis and Dimarogonas 1993), Engineering Design and Kinematics (Dimarogonas et al. 1971, 1992; Dimarogonas 1971a, b, c, e, f, 1981a, b, 1983, 1984a, 1987, 1988b; Dimarogonas and Sandor 1971; Dimarogonas and Maniatis 1976; Dimarogonas and Barman 1977; Dimarogonas and Massouros 1979b; Dimarogonas and Mourikis 1980; Panteliou et al. 1987, 1988; Chondros et al. 1987; Dimarogonas and Nakamura 1993; Panteliou et al. 1989, 1990, 1998; Kollias and Dimarogonas 1992b; Yiannopoulos et al. 1997), Rotor Dynamics, Turbo-machinery and Heat Propagation (Dimarogonas 1971b, 1972a, b, 1973b, c, d, 1974a, b, 1975, 1977b, 1983a; Kounas et al. 1972; Dimarogonas and Sandor 1973; Panteliou and Dimarogonas 1980, 1981a, b; Aspragathos and Dimarogonas 1982b; Panteliou and Dimarogonas 1982, 1983; Panteliou et al. 1983; Dimarogonas 1985a, b, 1986d, 1990a, b, f; Gomez-Mancilla and Dimarogonas 1992a, 1992b; Dimarogonas and Kollias 1992a, c; Kollias and Dimarogonas 1992a, 1994; Dimarogonas 1992a, h, 1993f, g, h, i, 1994b; Dimarogonas and Kollias 1993a, b; Gomez-Mancilla and Dimarogonas 1993a, b; Dimarogonas and Gómez-Mancilla 1994, 1996; Gómez-Mancilla and Dimarogonas 1995, 1996; Panussis and Dimarogonas 1997, 2000), Structural Dynamics, Damping, Fatigue and Crack Identification (Chondros and Dimarogonas 1979, 1980; Aspragathos and Dimarogonas 1980;

Andritsos and Dimarogonas 1980; Dimarogonas 1981c, d, 1994a; Dimarogonas and Massouros 1981; Aspragathos and Dimarogonas 1982a; Anifantis et al. 1982, 1983; Anifantis and Dimarogonas 1983a, b, c; Anifantis 1983c; Dentsoras 1983a, b, c; Aspragathos and Dimarogonas 1983, 1984; Anifantis and Dimarogonas 1984; Dimarogonas 1987a; Michalopoulos et al. 1987; Papadopoulos and Dimarogonas 1987a, b, c, d, 1992; Nikpur and Dimarogonas 1988; Dimarogonas and Papadopoulos 1988, 1990; Yao and Dimarogonas 1988; Rizos and Dimarogonas 1988; Gounaris and Dimarogonas 1988; Papaeconomou and Dimarogonas 1989; Chondros and Dimarogonas 1989; Dentsoras and Dimarogonas 1989; Actis and Dimarogonas 1989; Rizos et al. 1990; Gounaris et al. 1991; Dimarogonas 1992b, g; Dimarogonas and Syrimbeis 1992; Anifantis et al. 1994; Dimarogonas 1995d, e, 1996; Gounaris et al. 1996; Chondros et al. 1997a, b; Chondros and Dimarogonas 1998; Chondros et al. 1998a, b, c; Panteliou and Dimarogonas 2000a, b; Panteliou et al. 2001), Automotive Design (Chondros et al. 1994, 1997c, d, 1998, 2001; Papadimitropoulos et al. 1999; Kalogirou et al. 2000, 2002), Bioengineering (Nikiforidis et al. 1986, 1990; Dimarogonas et al. 1993; Dimarogonas 1993j; Civitelli et al. 1995; Panteliou et al. 1995a, b, 1996, 1999; Panteliou and Dimarogonas 1996, 1997a, b; Armamento-Villarea et al. 1997), and continuing work (Abbasi-Jahromi et al. 2009; Chondros 1993, 2001, 2005, 2009, 2010a, b, c, 2017, 2021; Panteliou et al. 2004, 2009a, b, 2012a, b; Stavropoulou et al. 2005; Christopoulou et al. 2006; Chondros and Labeas 2007; Anastasopoulos et al. 2010; Panteliou 2012, 2015; Papadogiannis et al. 2010, 2013, 2015, 2017; Chondros et al. 2007, 2013, 2015, 2016, 2019; Papadogiannis and Chondros 2013; Rossi et al. 2015; Chondrou et al. 2015, 2019). He published books in both Greek and English on a variety of topics on vibration engineering, computer-aided machine design, computational mechanics, rotor dynamics, structural reliability, natural philosophy, ancient and modern technology, ethics, poetry, issues of higher education policies, etc. He was a frequent author of articles in Greek national daily newspapers, and in English language magazines on political and educational issues, such as *Electrical World*, *Mechanical Engineering News*, *Chronicle of Higher Education*, *Science News*, *Scientific American*, *New Scientist, R&D Magazine*, *Business Week*, *Popular Mechanics*, *Technika Chronika*, the *Bulletin of the Technical Chamber of Greece*, and he presented several named lectures and keynote addresses on engineering and the arts. He became founding chairman of the annual International Poetry Symposium (now in its 60th year) and founding editor-in-chief of the Gordon and Breach/Harwood Academic Publishers international journal SYNOPSIS: *The Greek Studies Inde*x. Published articles and books are listed in chronological order in the References Section.

He was especially successful at building bridges between academic research and industry. His design portfolio includes several biomedical devices, a 500-ton railroad car, several industrial and institutional facilities, an integrated line of industrial laundry equipment, electronic packaging systems, and several electric power distribution systems. His latest research has been in design theory, intelligent manufacturing systems, bioengineering design, engineering diagnosis and prognosis, history of science and engineering, and ethics in engineering. He did consulting work with major corporations in Greece and the United States, such as General Electric Co., Pratt & Whitney Aircraft Hartford, Connecticut, Engine Rotor

Dynamics, 1973–1975, NORCA Machinery Corp. New York City, Design of a 500 ton railroad car, 1972–1974, Alfa Laval of Sweden, Greek Armed Forces Research Center, NDE, Intelligent Equipment Design, 1978–1982, Public Power Corporation of Greece, Non-destructive testing, 1984–1986, Modem Technology Inc., Athens, Greece, lndustrial Automation, 1975–1986, and local companies in St. Louis, such as Carter Automotive, Design Analysis of Automotive Fuel Pumps, 1989–1996, Hunter Engineering St. Louis, MO, Balancing Machinery Development, 1990–1998, Coin Acceptors, Inc., EckAdams Corporation and several law firms on patent disputes and product liability.

Major Industrial research programs undertaken by Prof. Dimarogonas include: Electromagnetic levitation casting of metals, Principal Investigator (PI). Sponsor: Showa Electric, Tokyo, Japan. 1990–1994 ($ 400,000). Acoustic Monitoring of Osteoporosis, (PI) Sponsor: WA Company. 1993-(60,000). Computer Integrated Manufacturing Lab, System Integrator and PI. Equipment, software, maintenance grants 1987–1996 ($ 2.5 million), corporate participation fees ($ 600,000). Diagnosis of Misaligned Rotors, (PI). Sponsor: Electric Power Research Institute, 1987–1988. Neural Network and Fuzzy Set Knowledge Base Systems for Fault Diagnosis, co-PI (Univ. of Patras). Sponsors: Greek Ship Register, Greek R&D Admin. 1990–1993. Reliability of solar collectors, Co-investigator (Univ. of Patras) Sponsor: Comm. of European Communities, 1986–1989. Intelligent Weapon Systems, PI (Univ. of Patras). Sponsor: Greek Army Research Center, 1977–1989. Diagnosis of traffic features by ground vibration analysis. Principal Investigator. Sponsor: Greek Army Research Center, 1987–1990. Industry Safety, PI (University of Patras). Sponsor: Center of Economic Planning and Research, 1983–84. Feasibility Study of Scrap Re-rolling, PI (Univ. of Patras). Sponsor: Greek Bank for Industrial Development, 1986–1989. Shock and Earthquake Response of liquid filled rotating cylinders, PI (Univ. of Patras). Sponsor: Alfa Laval, Sweden, 1984–1987.

Prof Dimarogonas' older son James is a senior researcher at the RAND Corporation and professor at the Pardee RAND Graduate School in Santa Monica CA. He currently conducts research in the areas of next-generation information technologies. Prior to RAND James (Demos) Dimarogonas spent 18 years at MITRE, serving in various leadership roles. MITRE is a not-for-profit organization, working in the public interest across federal, state and local governments, as well as industry and academia to tackle challenges to the safety and stability for a safer world. His younger son Peter (Panagiotis) Dimarogonas graduated from the Automotive Engineering Department of the University of Carbondale IL. He served in top managing positions in large firms of the automotive sector in Greece. Figure 2 shows Prof Dimarogonas in Peter's wedding ceremony in 1999, behind him his wife Cathy (Katerina) at his left the authors' younger daughter Dafni, Professors Mary and Gerald (Jerry) Gutenschwager, and Andromache Karanika James' wife, Associate Professor, Classics School of Humanities, Irwin University CA.

In 1993, Prof. Dimarogonas was appointed Springer Professor of Mechanical Engineering at the University of California, Berkeley for that academic year. He received the 1999 ASME Engineer-Historian Award for his many works on integrating the history of mechanical engineering. "He is truly a renaissance man worthy

**Fig. 2** Andrew D. Dimarogonas in 1999 in Peter's wedding ceremony, behind him his wife Cathy (Katerina), at his left the authors' younger daughter Dafni, Professors Mary and Gerald Gutenschwager of Washington University, and Andromache Karanika, James' wife, Associate Professor, Classics School of Humanities, Irwin University CA

of considerable recognition. His historical research often challenges current claims on innovation today" noted History and Heritage Committee Chair J. Lawrence Lee. In 1999 he was appointed Emeritus Professor at the University of Patras. He retained the W. Palm Professorship, from 1986 until he passed away on April 23 2000.

## *1.2 A. D. Dimarogonas Academic Family*

Andrew D. Dimarogonas, Engineer from the Design and Vibration Section of General Electric was the first Ph.D. student of Prof George Sandor (1912–1996) in 1968. George Sandor, Chief Engineer for Time, Inc. was the first Ph.D. student of Prof. Ferdinand Freudenstein (1926–2006) in Columbia University's Mechanical Engineering Department. During the 1960s an important motivation in kinematics occurred. Ferdinand Freudenstein who is considered the father of modern kinematics in America, brought Rudolf Beyer from Munich to Columbia, to offer a special graduate course on spatial mechanisms. Following that, Academician Ivan Ivanovich Artobolevski, a member of the Supreme Soviet of the U.S.S.R. and the foremost figure in mechanisms research visited Freudenstein, and an important connection of Columbia University was made with the mechanisms establishment in the Soviet Union. Professors Ferdinand Freudenstein, Ivan Artobolevski and George Sandor are shown in Fig. 3.

In 1991, in recognition of Freudenstein's 65th birthday, Professor Arthur Erdman, a Freudenstein academic grandchild, organized a Conference in Brainard in Minnesota entitled: *The origins of the theory of machines and mechanisms, a Tribute to Ferdinand Freudenstein* (Fig. 4). The works presented are contained in

**Fig. 3** Ferdinand Freudenstein (1926–2006), Ivan Ivanovich Artobolevski (1905–1977), and George Sandor (1912–1996)

the book entitled: *Modern Kinematics: Developments in the Last Forty Years*. In this Conference A. D. Dimarogonas presented the *Introductory Paper to the 40 Years of Modern Kinematics*.

The academic family of Prof. Freudenstein is growing constantly, in 2006 Professor Pierre Larochelle, of the Florida Institute of Technology, compiled a list of Freudenstein's academic descendents, reaching the fifth generation, and contained 500 names. The academic family of Prof. Dimarogonas is also growing, the list of articles in the References provides the continuing work of following researchers all over the world.

**Fig. 4** Brainard, Minnesota, 1991, 40 Years of Modern Kinematics, Conference, Ferdinand and Lydia Freudenstein, and their academic family, Andrew Dimarogonas next to Lydia Freudenstein

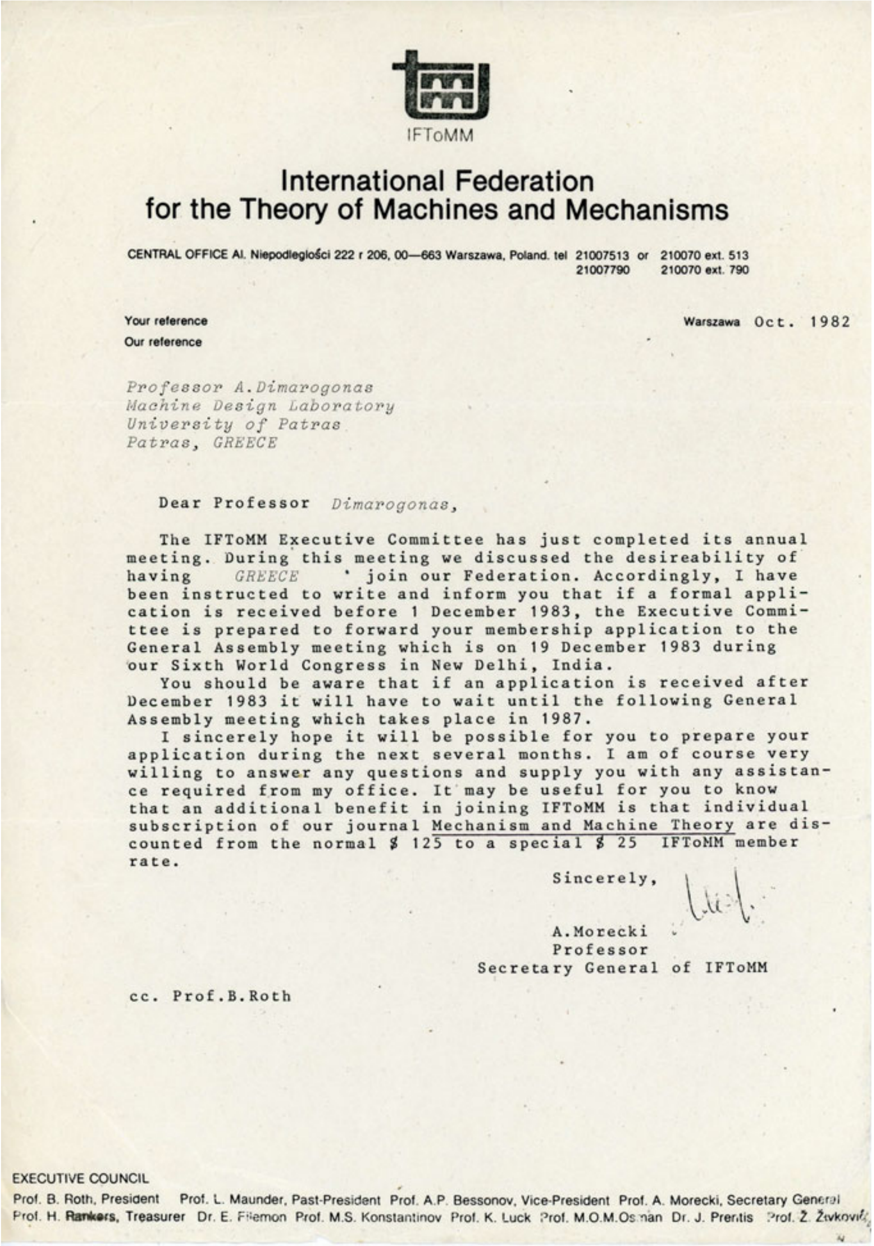
# 2 Prof. A. D. Dimarogonas Achievements

## *2.1 Founding IFToMM Greece*

In 1980 Prof. Dimarogonas contacted the International Federation for the Theory of Machines and Mechanisms (IFToMM) for Greece to join the Federation. On October 1982 Professor A. Morecki, then the Secretary General of IFToMM sent a letter informing that a formal application was required before December 1, 1983 in order to be forwarded to the IFToMM General Assembly meeting, scheduled on December 19 1983. The IFToMM Executive Council is reported on the letter; Prof. B. Roth President, Prof. L. Maunder Past President, Prof. A. P. Bessonov, Vice President, Prof. A. Morecki, Secretary General, Prof H. Rankers Treasurer, Dr. E. Filemon. Prof. M. S. Konstantinov, Prof. K. Luck, Prof M. O. M Osman, Dr. J. Prentis, Prof. Ž. Živcovičz. A subscription to the journal Mechanism and Machine Theory was offered with the application (Fig. 5).

Prof Dimarogonas, founder of the Greek Section of IFToMM had a good correspondence with both Prof Freudenstein and Prof. Artobolevski, and established the course Kinematics of Machines and Mechanisms, introducing a modern approach that the authors were first taught by Prof Dimarogonas in 1974, then students at the 3rd year of the Mechanical Engineering Department in Patras. The new course was apparently influenced by the Mechanism Science development of the time that was rapidly spread worldwide through the IFToMM. This effort continued by the first author who taught in the Mechanical Engineering Department of the University of Patras the courses *Kinematics of Machines and Mechanisms* and *Dynamics of Machines and Mechanisms* without interruption from 1990 to 2021. Design and Machine Elements were taught form the second author for more than 30 years, and a wealth of teaching material and assignments has been accumulated during those years.

As the authors recall, Prof Dimarogonas used to mention in class the fast development of high speed mechanisms and the connnection with Design and Vibration, mainly due to the need for high speed printers to support the increasing speed of computers. Then, as a design paradigm Prof. Dimarogonas refers to an incident at an International Conference in Moscow around 1976. Prof Artobolevski is the Chairman of the session, a famous proffessor presents a rubber model of a huge Novikov gear, his assistants rotate the mechanism on stage, the audience applauses for the gearing high efficiency, and after the auditorium becomes quiet, the Chairman asks for a question: what is the material used for the model and the gearing in the field, usually in the outer space, and reminds the fact that the thermal expansion factor is quite opposite for the two materials. The presenting authors of the work and the audience were back in order.



IFToMM

**International Federation for the Theory of Machines and Mechanisms**

CENTRAL OFFICE Al. Niepodległości 222 r 206, 00—663 Warszawa, Poland. tel 21007513 or 210070 ext. 513
21007790 210070 ext. 790

Your reference
Our reference

Warszawa Oct. 1982

*Professor A.Dimarogonas*
*Machine Design Laboratory*
*University of Patras*
*Patras, GREECE*

Dear Professor *Dimarogonas,*

The IFToMM Executive Committee has just completed its annual meeting. During this meeting we discussed the desireability of having *GREECE* join our Federation. Accordingly, I have been instructed to write and inform you that if a formal application is received before 1 December 1983, the Executive Committee is prepared to forward your membership application to the General Assembly meeting which is on 19 December 1983 during our Sixth World Congress in New Delhi, India.

You should be aware that if an application is received after December 1983 it will have to wait until the following General Assembly meeting which takes place in 1987.

I sincerely hope it will be possible for you to prepare your application during the next several months. I am of course very willing to answer any questions and supply you with any assistance required from my office. It may be useful for you to know that an additional benefit in joining IFToMM is that individual subscription of our journal Mechanism and Machine Theory are discounted from the normal $ 125 to a special $ 25 IFToMM member rate.

Sincerely,

A.Morecki
Professor
Secretary General of IFToMM

cc. Prof.B.Roth

EXECUTIVE COUNCIL
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**Fig. 5** The letter of acceptance of Greece as a member in IFToMM, from Prof. Morecki to Prof. Dimarogonas, October 1982

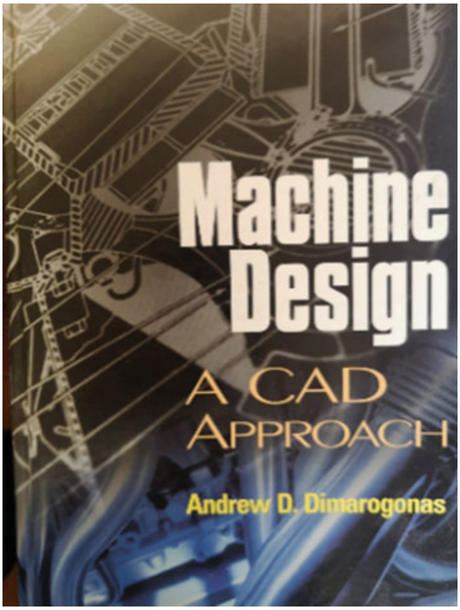


**Fig. 6** Andrew D. Dimarogonas, Machine Design, A CAD Approach, John Wiley and Sons, 2001

## 2.2 *Machine Design*

**Computer-Aided Machine Design** Professor Dimarogonas' books on computer-aided machine design in 1988, MELAB computer programs for mechanical engineers in 1993, Prentice-Hall, and the last book *Machine Design, A CAD Approach* (John Wiley and Sons, 2001) won him international acclaim as a leading expert in the field of mechanical design (Fig. 6). The historical evolution of the art of design is presented in a way to reveal the gradual development of the rules of an axiomatic foundation. The philosophical foundation of knowledge, aesthetics and ethics are discussed in order to identify their implications in engineering design. According to the author the first design theory was part of the aesthetic theory. Beautiful included also functional (useful) and ethical (good) implications. Their development and the relation of the function with the form and the ethical dimension is prevailing throughout the book, forming the intuitive knowledge required for machine implementation with methods of artificial intelligence. In the rhetorical question, *What is Engineering*? he refers to the famous jazz musician Louis Armstrong, once asked to define jazz. His answer was "If you got to ask, you'll never know". Aristotle's idea on engineering incorporating a sense of wonder is mentioned too: Nature works against man's needs, because it always takes its own course. Thus, when it is necessary to do something that goes beyond Nature, the difficulties can be overcome with the Assistance of Engineering. Mechanics is the name of the engineering discipline that helps us over those difficulties; as the poet Antiphon put it, "engineering brings the victory that Nature impedes".

The book describes the evolution of the Design theory, and its relationship with the Natural Science and Mechanics. Initially in history of engineering conception, design, and manufacture were the work of a single person and consequently, the first products were simple and of human proportions. The first machine designers were the master builders of the Potamic Civilizations (Mesopotamia, India, China, and Egypt). Those designers rose to the level of engineering in the Thalassic (great seas) societies of ancient Greece and Rome. Much later, mass production caused the breaking of this process into distinct smaller ones and led to the separation of design from manufacturing. However, the principles underlying design activity were investigated very early in history. The philosophical foundation of knowledge, aesthetics and ethics and their implications in engineering design are discussed in the introductory chapter of the book. The influence of natural philosophy in the 6th and 5th Centuries BC in the philosophical inquiry, and the scientific method developed in the 4th to 1st Centuries BC that have contributed to the establishment of mechanics and the principles involving the initial steps of building machines and its evolution with the fundamental axioms of machine theory from the classical times up to modern era, are further discussed.

The Dimarogonas' book *Machine Design—A CAD Approach* provides an insight in the evolution of systematic Design since the Alexandrian Times. The abstract set of design principles that appeared in Europe from J. Weisbach, F. Redtenbacher and his student F. Reuleaux (1854) who addressed separately the function and the form considerations in two ground rules (Grundsaetze) of mechanical design: a. (Function) The design must provide a uniform satisfaction of the design requirements. b. (Form) The form of the design embodiment must have the highest possible symmetry.

In 1964 Sandor proposed a seven steps strategy for machine design that is similar to that of Filippo Brunelleschi, a Renaissance architect famed for designing the cupola for Santa Maria del Fiore in Florence in the 1420s. He introduced a method of design based on a six-step design process, identical in essence to the design principles of Archimedes, consisting of 1. analyzing the design requirements, 2. making a concept design, 3. making a detailed design, 4. planning the manufacturing process, 5. manufacturing the parts and 6. assembling the parts. Brunelleschi's six-step design process is considered the first systematic design process in engineering history and was carried out for 500 years. The seven steps proposed by Sandor are: formulation of the problem, design concepts, synthesis, analyzable model, analysis-experiment-optimization, presentation. Similar sequential design procedures were in use until the 1970s.

In the traditional machine development process, each step is conceived of as a unit with clear inputs and outputs. Steps further downstream, such as Manufacturing Process Development, are not supposed to start until the results of previous steps, such as Component Design, are well defined. This "production-line" view of the development process assumes that time is wasted in downstream steps if upstream steps have not yet been completed, with plans solidified. Although it is true that downstream work must take upstream decisions into account, the major problem not dealt with in the traditional model is that upstream steps may arrive at results that are unrealistic, impractical, or not optimal for downstream implementation.

The solution of the problems investigated in sequential engineering was the formation of multifunctional design teams that include personnel of all sections-activities of the design/manufacturing/production/distribution/finance/marketing cycle so that the development of the design is concurrent in all fronts. Concurrent Engineering is the ideal of planning and implementing all machine development steps, from early product conceptualization to delivery and service, as early as possible. Team members are responsible for each step, working together throughout. The concurrent engineering model aims at starting all development process steps as early as possible, even simultaneously. Its success comes from each step influencing the other as the development process moves forward. With sufficient communication between people responsible for each step, practical and optimal results are more likely for all steps.

By the 1980s when the notion of engineers working on product design in teams manufacturing and mechanical engineers took hold, many engineering firms adopted this concept, called concurrent engineering. Further, Dimarogonas stresses the switch to concurrent engineering and the change in the way engineers do their work, with the advent of computer aided design, thanks to the revolution of computing that took place with the emergence of computers in the 60ies. Computation provided a third pillar to the classical two pillars of the scientific method, theory and experiment, a pillar overlapping the traditional two, but expanding each in ways never dreamed of before, and around that time has revolutionized engineering design.

The book can be considered as the most advanced approach in modern engineering design, by closing the gap of machine design theories before 1960, when computer-aided design (CAD) emerged in the 1960s out of the general acceptance of fast digital computers as tools to aid the design of complex systems. At that time, the most progressive industries introduced computer methods to aid their machine design effort, using modern optimization techniques, with the aid of computer graphics and computerized structural analysis. Although the emphasis is given to subjects more particular to computer application, the book does not rely exclusively upon computers, but first presents the methodology for longhand calculated solutions of machine design problems in the tradition of Reuleaux and the newer texts by Niemman and Shigley.

The book incorporates Kinematics and the design of mechanisms. Complicated mechanisms synthesis with the presence of hydraulic, electric, variable mass, and other types of links, and the application of optimization techniques are presented too. Robotic manipulators synthesis, dynamics and vibration analysis, along with clearances, lubrication, elasticity, damping, acoustics and noise control, and diagnostics issues are mentioned in the text.

Computer methods in analysis and design are used throughout the book. The book contains an optical disk with additional material on specific subjects along with a selection of calculation algorithms presented in the text as design examples, i.e. Bearings, Bolts-Rivets-Welds, Clutches-Brakes, Design Methodology, Flexible Elements, Force Analysis, Gearing, machine Kinematics, Section properties, and not limited to Stress Analysis. An integrated algorithm, MELAB-SIMULINK, provides the capability of connection with an A/D converter and data analyzer for vibration analysis.

In addition, the algorithm performs structural analysis, dynamics of structures and fatigue prediction, kinematic analysis, gears, cams, flexible kinematic elements, bearing design, bolts and joints design. The algorithm performs Finite Elements analysis, optimization methods, and various mathematical tools, also incorporating an Expert System.

The aim of the book *Machine Design A CAD Approach* (published after Dimarogonas passed away by Prof. Sofia Panteliou, one of the first of Dimarogonas Ph.D. students and scientific collaborator) is to find a sensible and delicate balance between the intellectual activity that goes into a machine design effort, and the computer assistance that a machine designer can have. In this frame, computer aided design is meaning computer "aided" design and not computer "made" design.

An overview of the pedagogical approach of the book is described in *Appl Mech Rev* Vol 54, no 4, July 2001, p. B65, Book Reviews, Reviewed by G Lewis (Dept of Mech Eng, Univ of Memphis, 312 Eng. Bldg., Memphis TN 38,152), as: *In the discussion about pedagogical approaches in the field of mechanical engineering education, perhaps no issues are more contentious than those that deal with the definition of design, how to teach it, and methods to ensure its seamless integration into the curriculum. Thus, any new book on the subject of mechanical engineering design is awaited with bated breath, to see the extent to which its contributions to the debate on the aforementioned issues and other pertinent matters are informative and/or innovative. It needs to be stated at the outset that this text does not disappoint. It takes a decidedly bold new approach to the subject, successfully synthesizing well established principles with evolving concepts. In the end, the student (whom one suspects is the primary, if not the only, intended readership) is given a treat, spread over an Introduction section, 14 chapters, and close to a thousand pages. Taxonomically speaking, the material in this text may be divided into three groups: description of the historical evolution of machine design as a key engineering process; the principles of machine design; and the applications of these principles to specific cases.*

Based on the concept of *concurrent engineering*, the book offers a great selection of algorithms that help the reader and the engineer to solve everyday practice problems. An example of a quick-return mechanism described in the text is animated through a working model program (Fig. 7), already contained in the optical disk (the linkage file is saved as QuickRet.wm). For this problem an Excel algorithm is also provided and the results are also shown in Fig. 7.

**A series of works on Design and the evolution of Design Theory are cited in the References in the Design section. Machine Design Laboratory University of Patras** While at the University of Patras, Prof. Dimarogonas developed the Machine Design Laboratory from scratch starting with his appointment in 1974. At the time of his departure in 1986, the laboratory had grown to a total floor area of 9,100 square feet with approximately one-half million dollars' worth of high-tech equipment including a Data General mini-computer, 10 Apple and IBM Personal Computers on a local area network, experimental robots, and vibration and lubrication test rigs (Fig. 8). An

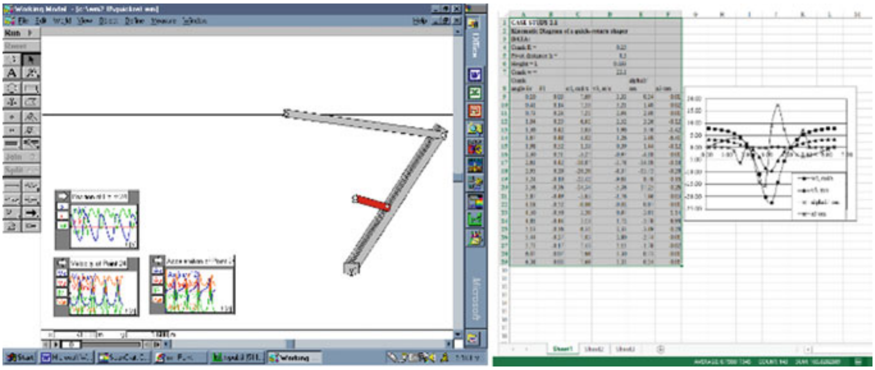

**Fig. 7** Quick-return mechanism

apparatus developed by Prof. Dimarogonas for vibration measurements and crack identification of a free-free bean with MELAB-SIMULINK is shown in Fig. 8 too.

The Machine Design Laboratory is equipped with a large number of mechanisms models and laboratory equipment including a full set of planar mechanisms, cams, gears, robotic arms, solar panels orientation mechanisms, automatic and pneumatic control devices. Models of machines and mechanisms of historical importance were designed and constructed from graduate students under his supervision. All those mechanisms are still in operation as laboratory equipment for teaching and demonstration purposes, as well as for research. A wing of an F-104 fighter jet was used for dynamic analysis with the aid of an IRD Mechanalysis 3 kW vibrating table. The STRUDL FE program was used for the evaluation of the eigenvalues and eigenvectors of the wing structure for varying support conditions, to simulate flaws. A lay-out of an automotive drive-train consisting of a 1970 1000 cc OPEL petrol engine with a 4-shift gearbox, drive axle, rear axle with differential and brakes is in operation. A Watt-governor provides stable engine revolution through a linkage connected with

**Fig. 8** Machine Design Laboratory, University of Patras, vibration measurements of a free-free cracked bean with MELAB-SIMULINK

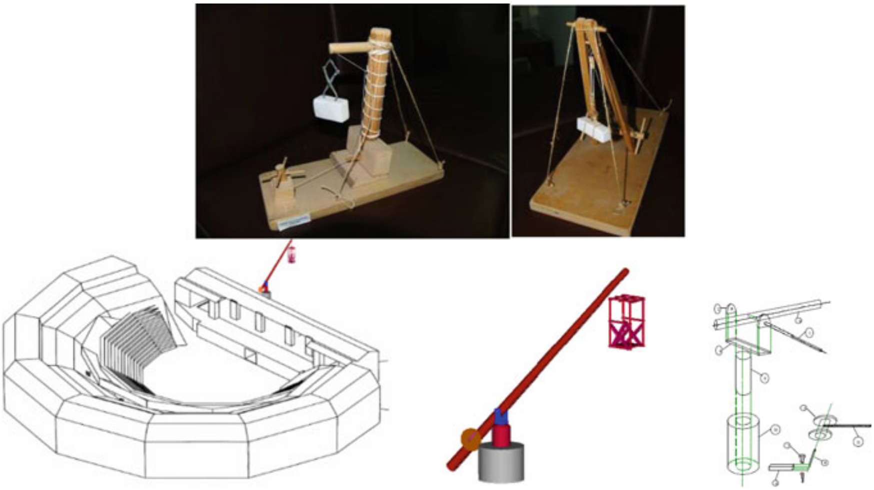

**Fig. 9** Reconstruction of ancient lifting devices of the fifth century BC. From left, the monokolos, the dikolos, and below the Deus-Ex-Machina reconstruction in 1993

the throttle. Two opposing gearboxes with the primary and secondary axles connected in series are used to calculate friction losses under full load. Torque is applied in the series connected axles of the gearboxes simulating full load. A 10 kW electric motor drives the gearboxes while the power consumed is recorded, and the temperature of the lubricating oil is monitored. Thus, operation of the gear boxes in full power is simulated and the efficiency yields from the power consumed to drive the gearboxes and the thermodynamic losses. The principle of operation of the device was used in shipyards in Japan since the 70s for the evaluation of the efficiency of the propellers speed reducers.

A wear-friction machine incorporates two trucks gearboxes connected in series for constant speed ratios in the rotating disk. Experimental devices were developed for the study of bearings wear and lubrication operating at different loading, temperature and lubrication conditions. An apparatus for the evaluation of speed and oil characteristics on pressure distribution for a model of Mitchell bearings used in ship propellers-axles applications is used both for demonstration and research (Fig. 8).

Ancient machines and mechanisms models are exhibited in the Machine Design Laboratory. A digital library of graduate theses concerned with the design of mechanisms models also exist (Fig. 9).

## 2.3 *Vibration Engineering*

**Tracing the Origins of Vibration Theory** Prof. Dimarogonas, an expert in vibrations and mechanical design, had a special interest in the history of mechanics.

As an engineer-historian, Professor Dimarogonas scrutinized many major scientific libraries in the United States and Europe for source material. He documented that the fundamental axioms of design were discovered during the middle of the last century in Europe and traced the origin of vibration theory to Archimedes and others of that period by unearthing obscure documents in continental libraries. He brought to light certain important historical developments in the field of dynamics and vibrations that were either glossed over or not fully understood.

In the paper *The Origins of Vibration Theory*, in the May 1990 issue of the *Journal of Sound and Vibration* Prof. Dimarogonas probes the origins of several scientific tools and principals. He also mentions that Pythagoras of Samos (ca. 570–497 BC), developed a scientific axiom that previously had been thought to have been the brainchi1d of eighteenth century scientists. Pythagoras, a nearly contemporary of Buddha, Confucius and Lao-Tse, and a student of the Ionian School after travelling himself to Babylon and Egypt, and probably India, moved from Samos to the Croton of South Italy and established the Pythagorean School, the first institution of Higher Education and Scientific Research. The primary contributions of the Pythagorean School were the developments of the theory of numbers and the theory of music and harmony. Although the term 'vibration' was used from the Aeschylus times the difference in the pitch of sound was understood since the evolution of music. It has been suggested that a musical instrument existed in 13,000 BC, but it is certain that the understanding of the music and of the consonance dates back to 3000 BC to China where the philosopher Fohi wrote two monographs on the theory of music. Pythagoras has quantified the theory of music and related it to his theory of numbers.

In *Science News* a Weekly Newsmagazine of Science, on May 12 1990 (vol. 137 No. 19 p. 295) an article by J. Amato refers to a debate of historians whether the ancient Greeks as high-minded theoreticians eschewed practical, hands-on investigation versus Andrew D. Dimarogonas' of Washington University in St. Louis arguing that "the first known research laboratory" existed in ancient Greece some 25 centuries ago—long before modern-day controlled research sprouted in Renaissance Europe. Dimarogonas has reassembled several lines of historical evidence indicating that Pythagoras—the Greek mathematician, who lived around 560 to 480 B.C.—set up an acoustics lab in his home. Dimarogonas' claim pivots largely on the writings of the Roman scholar Boethius, who lived 1,000 years after Pythagoras died, and who probably had access to documents long since lost. Boethius recounts a story of unknown origin in which Pythagoras, after going into a metalworking shop, conducted impromptu experiments to learn how different hammers produced specific tones. As Boethius tells it, Pythagoras discovered that a hammer weighing half as much as another produced a note an octave higher no matter how much force was used to swing the hammer. Pythagoras also found that other sets of hammers with specific weight ratios produced other tonal consonances such as fourths. A drawing of the 16th century A.D. from Boethius plucking a monochord and Pythagoras conducting hammer experiments is shown in Fig. 10.

According to the story, Pythagoras returned home from the shop and conducted experiments on the relationship between objects' physical proportions and the tones they produce. His experiments included plucking strings of different lengths and

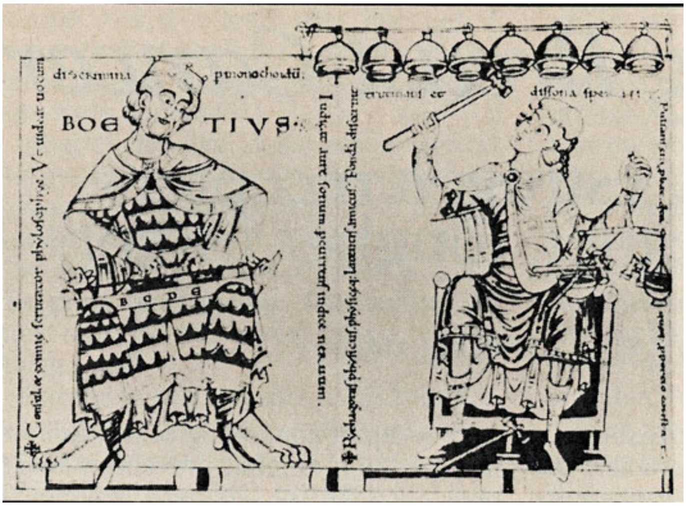


**Fig. 10** Drawing accompanying a manuscript by the Roman scholar Boethius (sixteenth century A.D.). Left frame shows Boethius plucking a monochord, an instrument allegedly designed specifically for acoustics experiment. Right frame shows Pythagoras conducting hammer experiments with bells in what may have been the first scientific laboratory

widths and hitting vessels filled with varying amounts of liquid. Dimarogonas summons further evidence from the drawing accompanying Boethius' manuscript (Fig. 10). Pythagoras is shown using a hammer to hit a series of hanging bells, while other hammers rest in the pans of a balance suspended from his other hand. To the left, Boethius himself appears with a so-called monochord, an instrument consisting of a single taut string whose length can be varied. The monochord "was deliberately designed and built to conduct experiments regarding the relation of the length of the string to the pitch of the sound".

The fact that for a (linear) system there are frequencies at which it can perform harmonic motion was known to musicians but it was stated as a law of nature by Pythagoras. Moreover, he proved experimentally with his hammer experiments that natural frequencies are system properties and do not depend on the magnitude of the excitation.

David Doak, Professor Emeritus of acoustics at the University of South Hampton, Great Britain, and editor of the *Journal of Sound and Vibration* concurs that while much of the classic writings of the philosophers and poets has been preserved through the ages, mainly through the efforts of Roman monks, the sciences did not fare so well. During the time of Caesar, Roman forces destroyed the Alexandrian Library in Egypt, laying waste to much of the history of the ancients. Almost no personal writings of some of the ancients, and none of Pythagoras', survived. This is what makes Dimarogonas' research important, novel and revealing, comments Prof. Doak.

Werner Soedel, Professor of mechanical engineering, and Bernard Foley, Professor of history at Purdue University contend that Dimarogonas' research will have reverberations in the scientific community and the historical one, as well as an outgrowth concerning engineering problems that perplexed the ancient Greeks. Dimarogonas views his research not as an apologia for Greece or the ancients of other countries, but an intellectual journey to the beginnings of scientific thought in his area of expertise: mechanics and design.

Professor Emeritus Richard Hartenberg, of mechanical engineering at Northwestern University, who taught History of Engineering for 29 years refers to Dimarogonas' paper as: It is the first reference to a laboratory appearing this early. And it is the first time the word laboratory has been associated with one of the "old boys" Interesting hardware, such as the water clock, the water organ and the force pump, came into the picture around 250 BC with Ktesibios, we do know. But the era before that is wide open to interpretation.

**Vibrating Beams and Structures with Flaws** Dynamic response of cracked rotors was identified by Dimarogonas in GE around 1970. He used the elastic hinge model to observe that the response is similar with the rotors with dissimilar moment of inertia. Dimarogonas in GE had to cope with the problem of torsional vibrations of shafts resulting in heat generation due to material damping. In some cases, temperatures can reach high values affecting the reliability of machine members. Such a case was reported for the generator exciter shaft failures at the Southern California Edison Mohave Station 1 and 2, due to torsional vibration resulting from sub-synchronous resonance or the electromechanical system. The heat generated produced high temperatures which destroyed the exciter insulation and accelerated shaft failure.

Analyzing flawed structures is a hugely important technological problem for aging turbo-generators, aircraft, and other rotors (generally, built in the 1960s and the 1970s with 30-year operating life spans that were to be extended). Damping plays an important role in technical practice for various loading cases. For each material many mechanisms generating damping appear regardless of material type. Degradation of structural integrity of materials is related to strength decrease. Evaluation of the effect of defects on materials strength is very important consideration in engineering technology. The origin of these defects may be fatigue or static loading and their presence influences the behavior of a material towards mechanical stresses.

A crack on an elastic structural element introduces considerable local flexibility due to the strain energy concentration in the vicinity of the crack tip under load. Long ago, this effect was recognized and the idea of an equivalent spring, a local compliance, was used to quantify in a macroscopic way the relation between the applied load and the strain concentration around the tip of the crack. Dimarogonas introduced the local flexibility model for a crack for vibration analysis of cracked beams in the70s. He combined this spring hinge model with the fracture mechanics results, and developed a frequency spectral method to identify cracks in various structures. This method related the crack depth to the change in natural frequencies of the first three harmonics of the structure for known crack position. A series of Ph.D. dissertations supervised by A. D. Dimarogonas gave both quantitative and qualitative results on the subject (Chondros and Dimarogonas 1979, 1980; Aspragathos and Dimarogonas 1980; Andritsos and Dimarogonas 1980; Dimarogonas 1981c, d, 1994a; Dimarogonas and Massouros 1981; Aspragathos and Dimarogonas 1982a; Anifantis et al. 1982, 1983; Anifantis and Dimarogonas 1983a, b, c; Anifantis 1983c; Dentsoras 1983a, b, c; Aspragathos and Dimarogonas 1983, 1984; Anifantis and Dimarogonas 1984; Dimarogonas 1987a; Michalopoulos et al. 1987; Papadopoulos and Dimarogonas 1987a, b, c, d, 1992; Nikpur and Dimarogonas 1988; Dimarogonas and Papadopoulos 1988, 1990; Yao and Dimarogonas 1988; Rizos and Dimarogonas 1988; Gounaris and Dimarogonas 1988; Papaeconomou and Dimarogonas 1989; Chondros and Dimarogonas 1989; Dentsoras and Dimarogonas 1989; Actis and Dimarogonas 1989; Rizos et al. 1990; Gounaris et al. 1991; Dimarogonas 1992b, g; Dimarogonas and Syrimbeis 1992; Anifantis et al. 1994; Dimarogonas 1995d, e, 1996; Gounaris et al. 1996).

The discrete-continuous models are by far the most commonly used models in dynamic analysis of cracked beams. The basic concept is the introduction of additional boundary conditions at the crack location where two intact beams are connected with a flexibility matrix whose components are determined by linear fracture mechanics. Hence, the most important work by this approach is to determine the local flexibility matrix. The main limitation of the flexibility approach is that it can only be applied to one-dimensional problems and works well mostly for fundamental structural elements. However, the discrete-continuous crack models are advantageous in many aspects. For instance, the intact part of a structure containing no cracks can still be modelled with corresponding partial differential equations; cracks only increase the boundary conditions that require less computational effort than most finite element methods involving fine meshes around the crack region. The local compliances based on linear fracture mechanics can be verified as well as calibrated with a wealth of experimental data available in literature. The flexibility method can be easily extended to construct special crack elements for finite element analysis. The local flexibility method can be used to investigate an edge crack on a cracked beam that vibrates in coupled bending and torsion modes.

While natural frequencies are relatively easier and more accurately measured than other modal parameters, solving an inverse problem for crack detection based only on changes in natural frequencies is not so easy, considering the fact that natural frequency has a global nature while damage in most cases is a local phenomenon. However, if the crack is the most possible failure mode and no other form of damage exists, detecting the crack by natural frequencies is possible, even with the presence of measurement error. The key issues in developing a proper modelling technique of a cracked beam is to model the crack more accurately, and furthermore identify the variation in the stress field due to the opening and closing of the crack (crack breathing) and the stress-strain field complexity in the region of the developing crack. Also, the modification of the stress field induced by the crack is decaying with the distance from the crack or flaw and a direct method relating flaw position and size with stiffness change is not easy to be developed (Chondros and Dimarogonas 1979; Aspragathos and Dimarogonas 1980).

On the other hand, damping is a very important material property in vibrating structures made out of materials facing crack development or change in porosity. Damping properties of structural materials have a great potential for NDI in large structures, in the aviation and ship industry. From all damping mechanisms thermodynamic damping has been shown to be an important alternative in structural integrity assessment through dynamic evaluation of defective structures (Chandros et al. 1998c; Panteliou 2000a, b; Panteliou et al. 2001). In the works co-authored with the second author it was shown that this damping category accounts only for the specific structural defect and can be used as indicator of crack severity or change in porosity on conventional or advanced materials. Professor Dimarogonas' methodology for monitoring vibrations of these systems permits the diagnosis of the need for correction or replacement.

In 1990, the Hu-Washizu-Barr variational formulation was introduced by Prof. Dimarogonas to develop the differential equation and the boundary conditions of the cracked beam. The method is based on the general variational principle and the independent assumptions about the displacement, the momentum, the strain and the stress fields of the cracked beam, for the derivation of the equations of motion. The crack is introduced as a stress disturbance function, the stress field is determined by fracture mechanics methods, and thus a-priori assumption for the extent of the stress field due to the crack is not required. A wealth of Dimarogonas papers in scholarly journals and conferences focuses on issues of crack identification (Chondros et al. 1997a, b, 1998a, b, c; Chondros and Dimarogonas 1998).

An optimization technique was developed by Dimarogonas to obtain the minimum-radius intervals of the solution. To assure monotonicity and absolute inclusion, necessary for convergence to the exact interval, a converging interval halving sequence was developed. For numerical tests of the method a Monte Carlo solution was developed. Results showed that interval analysis can predict the range of the eigenvalues with sufficient accuracy. The response of a linear system to general excitation for interval matrices of the system parameters cannot be found with interval evaluation of the commonly used numerical techniques because if they are applied directly, the solution intervals diverge. Interval modal analysis and the interval solution of the eigenvalue problem was further developed.

A heteroassociative neural network was used to map the existing knowledge and acquire new knowledge in learning sessions. The inputs could be binary, fuzzy and interval variables. To process the diagnosis in a back-propagation mode, interval calculus is utilized in algebraic and matrix operations and the diagnosis results in interval output parameters, the identification scores. Interval calculus programmed in a software package including arithmetic, function and matrix operations allows for interval computations (The algorithm is contained in the optical disk of the book *Machine Design—A CAD Approach*. Available experience from Prof. Dimarogonas for failure diagnosis in turbomachinery was utilized to initially teach the system. Additional diagnoses can be taught to the system and additional features and diagnoses defined. Convergence of the procedure depends on the monotonicity of the functions used. For usual networks and threshold functions, convergence is warranted.

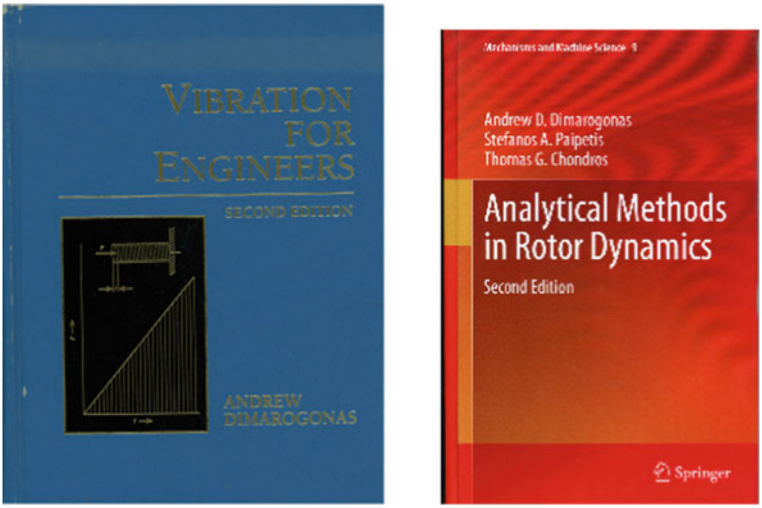


**Fig. 11** A. D. Dimarogonas (1996) Vibration for Engineers, Second Edition, Prentice Hall, Englewood Cliffs, New Jersey, and Dimarogonas A. D, S. A. Paipetis and T. G. Chondros, (2013) Analytical Methods in Rotor Dynamics, 2nd Edition, Springer, Dordrecht, Heidelberg, New York, London

Dimarogonas' books in Vibrations published in 1976, 1992 and the last edition *Vibration for Engineers* in 1996, provide a comprehensive presentation of the evolution in Vibration Engineering along with current research activities, and industrial applications mentioned above. The book *Analytical Methods in Rotor Dynamics* originally appeared in 1983 by Professor A. D. Dimarogonas co-authored with Prof. S.A. Paipetis (1938–2020), and soon went out of print. The last edition in 2013 co-authored by the first author too, study the behavior of cracked structural members and rotating machinery, incorporating methods of analyzing flawed structures with the application of the variational principle (Fig. 11).

**CAD and Vibration Laboratory in Washington University in St Louis MO** Prof. Dimarogonas was instrumental in the development of the Washington University Computer Integrated Manufacturing Laboratory (CIMlab), a 10,000 square-feet facility featuring innovative applications of computers that promote efficiency through automated manufacturing and computer-aided design. In the basement there was a large computer aided design and drafting facility, with a capacity of 30 working stations for the McDonnell-Douglas engineers. Dr Safi, Technical Director of the St Louis McDonnell-Douglas plant was a professor of the Mechanical Engineering Department of the Washington University in St Louis in the 90s.

Among the laboratory equipment there was a mechanical vibrating table made by BALDWIN in the 50s, operating with the aid of an eccentric mechanism shown in Fig. 12. The apparatus was extensively used for the production of aluminium specimens with cracks of varying depths. A cantilever prismatic bar was vibrating at its natural frequency. An edge surface crack was initiated and its propagation was

**Fig. 12** Views of the BALDWIN vibrating table and the preparation of the cracked specimens, Washington University in St Louis, MO

monitored during vibration with a strobe-light. Different crack depths were available for the experimentation and evaluation of the analysis for crack identification in vibrating prismatic beams with surface cracks (Fig. 12).

### *2.4 The History of Technology*

During Professor Dimarogonas' career a strong interest in history continuously manifested itself in chapters of various books, technical papers, lectures, and particularly notable, a two-volume *History of Technology* (published in Greek). In his book V*ibration for Engineers*, his historical sketches of great engineers and scientists include those of Pythagoras, Galileo, Newton, Euler, Gauss, Lagrange, Laplace, Hertz, Stodola, and Timoshenko. Reviews and letters concerning his work on Pythagoras, for example, have appeared in Scientific American (July 1990, p. 25), R&D Magazine (September 1990, p. 3), The Chronicle of Higher Education (May 9, 1990, p. A10), Science News (May 12, 1990 (p. 295), and New Scientist (July 14, 1990, p. 23). The two volumes' books in History of Technology printed in 2001 are shown in Fig. 13.

Courses History of Technology I and History of Technology II are integrated in the curriculum of the Mechanical Engineering and Aeronautics Department of the University of Patras during the first and second semester every academic year. The course was first introduced in 1974 by Professor Andrew Dimarogonas in the newly founded (in 1972) Mechanical Engineering Department of the University of Patras. The authors, then students of the Department in the third year were also attending the new course. Course teaching was accompanied by students homework assignments to identify important, not strictly technical, aspects of engineering and engineering design, such as the emergence of engineering societies, the engineering

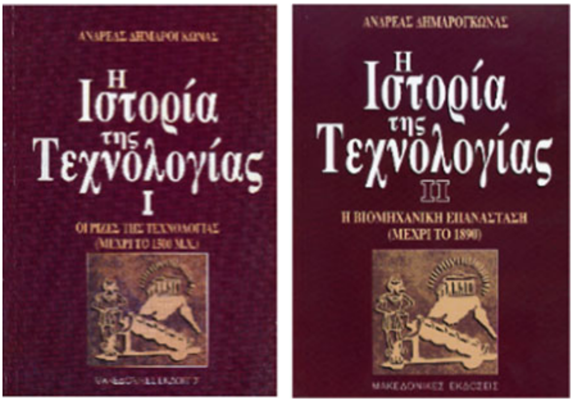


**Fig. 13** A. D. Dimarogonas' The History of Technology I, The Roots of Technology (Up to 1500 AD) and The History of Technology II The Industrial Revolution (Up to 1890), Macedonian Publications, Athens 2001

ethics, engineering aesthetics, the philosophers, artists' and poets' view of engineering. The history of engineering was also viewed for its cultural, economic and political impact on society.

A textbook *History of Engineering* (2 Vols. In Greek) first appeared in 1976 after the handouts distributed by Prof. Dimarogonas in class during his first lectures in 1974. The books' second edition followed in 2001 (Fig. 13). As an outline the following areas are highlighted: What is Engineering. Technology, invention and engineering. The primitive societies. The hand, the primitive tools. Production and the human society. The role of the domestication of animals and agriculture in the emergence of technology. Engineering as technology of scale. Early Engineering. Irrigation and Potamic civilizations. Mesopotamia, Asia Minor, Egypt, India, China. The Great Empires. Pyramids and public works. The first engineers: Amenhotep and Gudea. Early sources on Engineering. Mythology and the Bible. The emergence of Reason. Natural Science. Ionian School of Natural philosophy. Thales and electromagnetism. Pythagoras and vibration. Democritus and atomic physics. Engineering Science. Aristotle. Mechanical Engineering. The Pythagorean and the Alexandrian Engineers. Civil Engineering and Architecture. Roman Engineers. Chinese Engineering. Arab Engineering and Design Methodology. Middle Ages. Time reckoning and fluid power. Leonardo da Vinci. Alchemy, Chemistry. Renaissance. Galileo and Newton. Engineering Science. The Industrial Revolution, 1750–1830. The Age of Steam and Iron, 1830–1900. Modern Technology, twentieth century. The engineering professions. The professional societies. Engineering ethics. French Engineering. The Ecole Polytechnique and Napoleon Bonaparte. Mechanics. German Engineering. Solid and Fluid mechanics. The engine. American Engineering. The ways in which technology, broadly defined, has contributed to the building of American society from colonial times to the present. The West Point. The large-scale project. The Automobile. Electronics and Computers. Aircraft and Spacecraft. Bio-engineering. Case studies in engineering achievements and disasters. The Wright Brothers and the airplane, the Apollo Project, the tunnel under the English Channel, the Challenger disaster, the case of the DC10 design, the Hyatt.-Regency Hotel failure in Kansas city, the Bhopal disaster. The course introduces the student in the development of each of the major branches of engineering (e.g., CE, ChE, EE, ME, etc.) and its history. Each student will be expected to research the a particular engineering subject and write an essay, or will design and built a model of an engineering design historical importance.

## *2.5 Biomechanical Design*

**Osteoporosis and bone fracture healing diagnosis**. During the nineties Professor Dimarogonas turned his expertise towards biomechanical design and structural fault diagnosis and prognosis. Damping properties of bones can be used in a similar way in bioengineering as in large structures mentioned above. The case of bones, which from the mechanical point of view are considered as composites, has been treated through bone structural assessment by thermodynamic damping analysis and measurement. Damping results are shown to be very advantageous in comparison to all other data acquired with all existing conventional methods. The case of fractured bones, may be treated through bone structural assessment by thermodynamic damping analysis and measurement. This target requires the following: analytical formulation of thermodynamic damping changes due to changes in crack propagation, simulating the fractured bone architecture, design and construction of dedicated devices for damping measurements on bones to be used for testing, in comparison to measurements acquired with existing conventional methods, and as alternative means of bone structural integrity identification, diagnosis and monitoring of bone fracture healing.

A bone holistic modelling, in combination to design and development of a suitable measuring system, leads to accurate and competitive means for bone quality assessment, thus providing a competitive tool for bone density measurement. This procedure led to the development of a machine to diagnose osteoporosis using a wide-band sound sweep excitation with an integrated accelerometer for signal pick-up. The apparatus is shown in Fig. 14. A similar machine for non-destructive diagnosis of fatigue of materials before the crack initiation and propagation stages. He received five patents in this area from 1995 to 2002. (Several older patents in the areas of turbomachinery and machinery automation were assigned to the sponsoring organizations.).

**Fatigue Fracture of the Bjork-Shiley Heart Valve Strut** Repeated loading of the outer strut leg of the Björk-Shiley 60° convexo-concave (BSCC) valve results in fatigue crack propagation, with a duration from a few months to a few years. Sound and vibration analysis emitted from the strut of the BSCC valve due to impact was used to monitor the propagation of the fatigue crack before it would lead to the failure of one or both legs of the outlet strut. Analytical and experimental results established that the range of the fundamental natural frequency is 4,000–8,000 Hz. Analysis of sound emitted from the strut of the valve due to impact may be used to monitor the

**Fig. 14** A. D. Dimarogonas' Patented device to diagnose osteoporosis WU Lab, St Louis MO 1995

propagation of the fatigue crack before it would lead to the failure of the one or both legs of the outlet strut (Fig. 15).

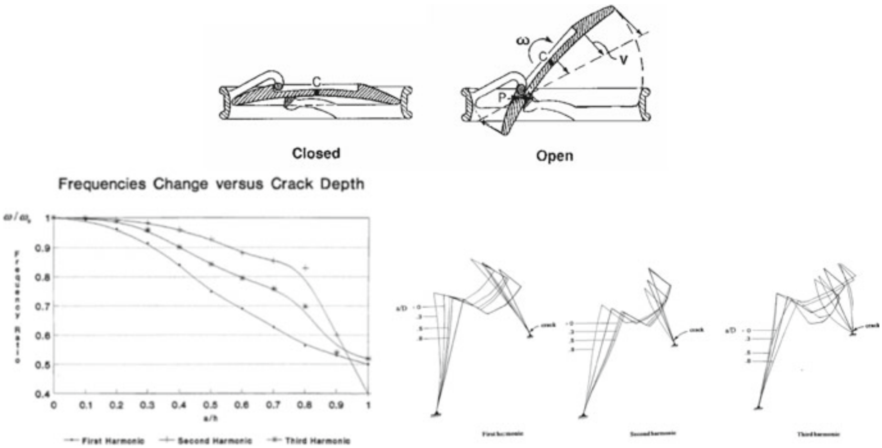


**Fig. 15** Cross-section of a BS60CC 29 mm tilting-disk valve in the closed and open position, inlet strut frequency ratio changes for various crack depths of the left strut leg, and the first three modes of vibration change for varying crack-depth

## 2.6 *Industrial Design*

**Controlled Contact Continuous Casting** A continuous casting mold, oscillating in 3 dimensions, providing a limited duration contact of molten metal with the mold was designed by Prof. Dimarogonas. A detailed R&D proposal was submitted in the Directorate General for Science Research and Development on April 1989. By controlling the oscillation amplitudes, frequencies and directions, the duration of the contact can be altered to keep the mold from overheating. The combination of lateral and longitudinal oscillation contributes to the axial motion of the cast form. Thus, the mold operates at any angle of inclination with the horizontal direction (Fig. 16). Consequently, very thin strips and rods can be cast at very high speeds because the mold can have any desired length. The improvement over conventional continuous casting is that the casting mold has a three-dimensional motion, any desired length and slope, a controlled duration contact between molten metal and mold and a no slip motion of the cast strand in the mold. This resu1ts·in elimination of the reheating and most of the hot rolling process with very substantial energy conservation, of the order of 40% in steel production.

It was found in the laboratory experiments that by selecting appropriate frequencies, amplitudes and phase angles of the lateral motions in the two perpendicular directions, and the cast strand can have also a rotary motion about its geometric axis.

**The Electro-Internal Combustion Engine** In 1976 the authors, then fourth grade students at the Mechanical Engineering Department of the University of Patras,

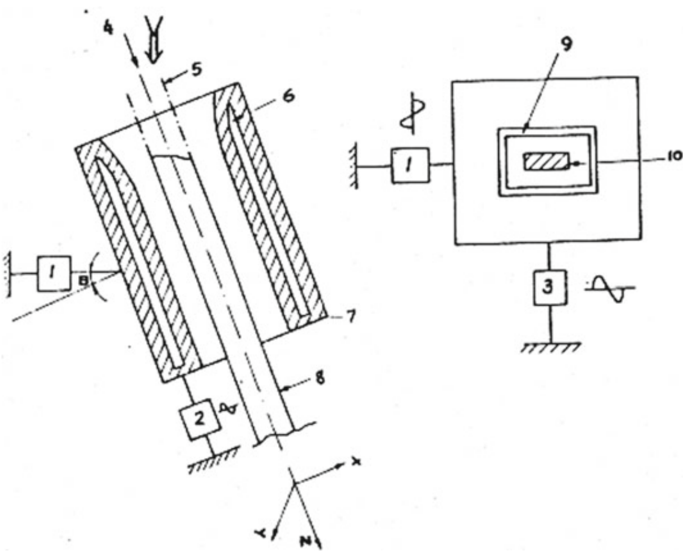


**Fig. 16** Two cross-sections of a mold vibrating in the two lateral directions and the direction of longitudinal motion of the cast strand

undertook the task to prepare a demonstration device of an Internal Combustion—Linear Generator Free-Piston Engine. The project was based on previous Dimarogonas' work: an Internal Report on E.I.C. (Electro-Internal Combustion Engine) to Lehigh University, Bethlehem, in 1973 and a Ph.D. thesis Supervision in 1974 on the Dynamics of the E.I.C. Engine on Digital Computer, again at Lehigh University, and the work Free Dynamics and Stability of the S-S Pair of a Free Piston Engine., by A. D. Dimarogonas and A. Barman published in *Mechanism and Machine Theory Journal* in 1977. Matrix methods already developed and applied by Hartenberg, Denavit, Uicker and Dimarogonas were incorporated in a newly developed study for the dynamics and stability of the operation of the free piston engine, which is essentially an S-S pair, constrained by two nonlinear springs, the compression chambers.

This innovative approach provides direct conversion of the energy released during the combustion into electricity by way of a floating piston. A magnetic core attached to the piston produces electricity at the windings of an appropriate stator. The two opposed pistons of the free-piston engine, the Electro-Internal Combustion Engine, form an S-S pair exhibiting certain interesting instability phenomena. The free dynamic response of this highly nonlinear system and its stability was studied and tabulated for a wide range of parameter constellation in the works of Dimarogonas. A computer program, based on this method, provides motion and force solutions for the complete motion cycle of the mechanism. From the design curves proper selection of the components' dimensions and mass were available for the prototype. The principle of operation of the E.I.C. engine is depicted in Fig. 17.

The basic dimensions of the engine refer to a given position of piston, i.e. x = 0. The design of the engine for the analysis is completely stated in terms of eight design parameters, defined as: $M$ mass of piston assembly, $D$ cylinder bore, $A$ cross sectional area of cylinder $\pi D^2/4$, $L$ stroke of piston, $F_1$ force acting on piston in combustion chamber, $F_2$ force due to electric piston, $F_3$ viscous damping force, and $F_4$ Coulomb

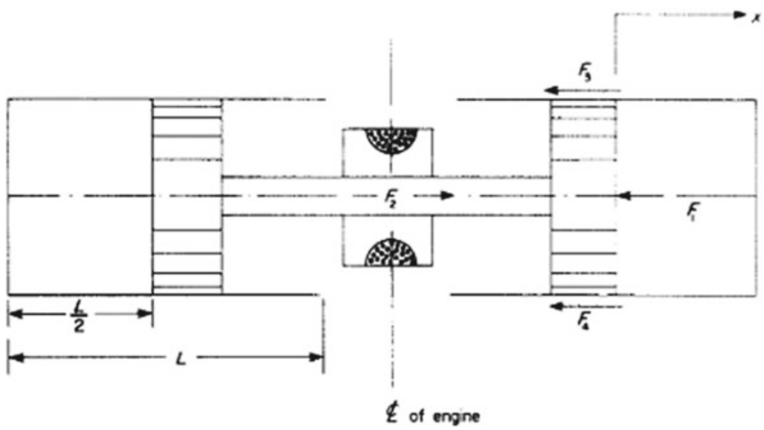


**Fig. 17** Principle of the EIC engine operation

friction force. The equations of motion for the piston assembly as functions of piston position, are:

$$M\ddot{x} = F_1(x) + F_2(x) + F_3(x) \mp F_4 \tag{1}$$

Then, for the homogeneous free oscillation problem incorporating design parameters and suitable engine operating conditions, the solution yields:

$$\ddot{z} + \gamma\dot{z} + \lambda\left\{(1-z)^{-n} - (1+z)^{-n}\right\} = \in \sin\omega t \tag{2}$$

where $z = (x/0.5L)$, $L$, piston stroke, $\gamma = C/M$, $C = \mu/d$, $\mu$, viscosity of the lubricant, $d$ distance between surfaces, $\epsilon = F_0/0.5ML$, $F_0 \sin\omega t = F_2$ force due to the magnetic field acting on the electric piston, $\omega$ the circular frequency of the piston oscillation. From Binomial expressions, Eq. (2) yields for very low damping:

$$\ddot{z} + \gamma\dot{z} + \lambda\left\{2nz + \frac{2n(n+1)(n+2)}{3!}z^3\right\} = 0 \tag{3}$$

Equation (3) has been investigated by Duffing in 1918 in the form

$$\ddot{z} + \gamma\dot{z} + az + \beta z^3 = 0 \tag{4}$$

Approximate analytical solution of Duffing's equation cannot be used to solve Eq. (2) due to complexities of higher order terms of $z$. Therefore, to take into account the effect of the higher order terms, a numerical method was employed. For the given value of damping coefficient $\gamma$, forcing function $\varepsilon$, frequency $\omega$, and different values of $z$, phase diagrams through several cycles were found with the aid of a digital computer and the results are shown for different forcing function in Fig. 18.

The orbit which is shown in Fig. 18 is for small value of forcing function $\epsilon$. Here the system behaves like linear. When the system forcing function $\varepsilon$ increases to 5000, the nonlinearity in the system is in control, (Fig. 18, right). Thus, a value of $z = 0.7$ is obtained up to $\omega/\omega_n = 1.3$ and drops suddenly to $z = 0.24$ at $\omega/\omega_n = 1.35$. Similar results were also obtained when the forcing function was increased to 10,000. There, $z = 0.82$ is obtained up to $\omega/\omega_n = 1.55$ and $z = 0.26$ at $\omega/\omega_n = 1.6$.

From the preceding analysis a 4HP, 50 Hz two-opposed cylinders Free-Piston engine was designed as a demonstration prototype. The design blueprints and the engine during the assembly process, along with the sketch of the stator and the reciprocating magnetic field windings, back in 1976, are depicted in Fig. 19.

Then, a proposal for an energy demonstration project for the construction and operation of a 1200 HP pair of two stroke Diesel Free Piston Engine with 600 V D.C. 900 KVA linear generator was submitted in collaboration of the University of Patras with the Greek Ministry of Transportation in the Commission of the European Communities in 1987. The proposed project, with substantial aid from the Technical Director of the National Railroad Organization, Chief Engineer Byron Papageorgiou, would substitute a 1200 HP conventional DIESEL-Generator power unit for the

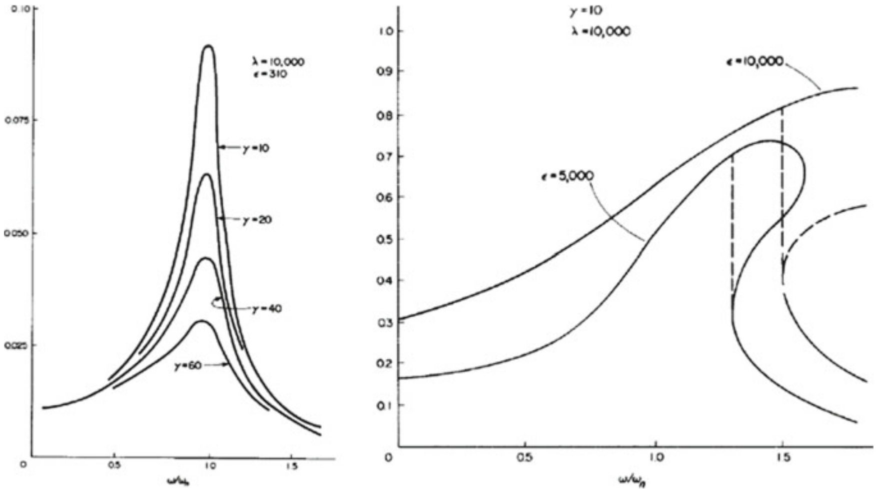


**Fig. 18** Vibration spectrum of the EIC engine, left: low nonlinearity, right; high nonlinearity

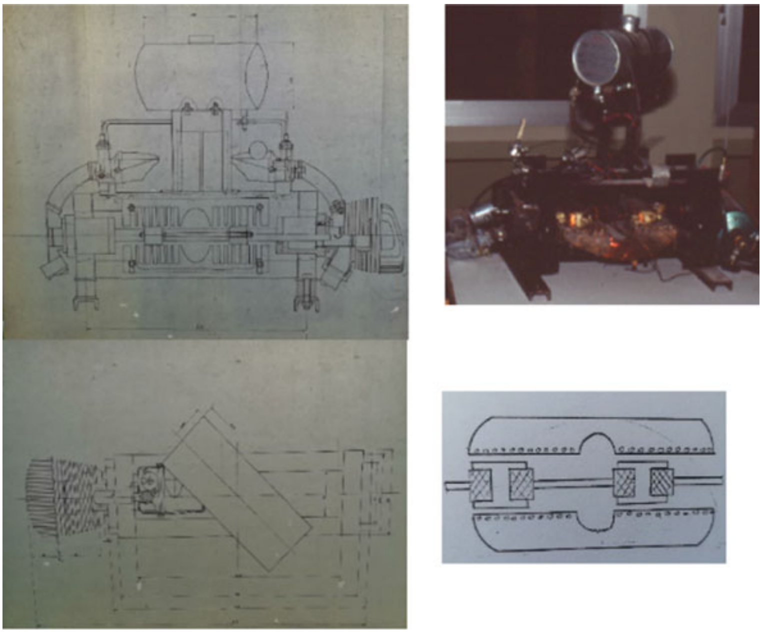

**Fig. 19** Blueprints from the EIC engine design, the assembly phase of the E.I.C. engine, sketch of the electric stator and reciprocating magnetic field windings, Machine Design Lab, University of Patras, 1976

**Fig. 20** One of the first 300 ton Schnabel Cars of GE in 1960s (left), center a 400 ton car with a girder system in the 70s (Courtesy of General Electric Company), and right a 500 ton car of the new design (Courtesy of ABB)

electric propulsion of a railroad locomotive. Six power elements of a linear 200 HP, 600 V generator would be connected directly with each of the six 600 V D.C. motors of the locomotive. As a result, 10% increase in efficiency was expected, along with 50% reduction to power unit mass. The machine would operate with adjustable compression ratio according to traffic conditions. Estimated cost of the project was 1,400,000 USD. The proposal did not go well, it was the time of the emerging high speed electrified trains. Today, 35 years after the proposal, the electrified train line is 160 km away from Athens, still 40 km required to reach Patras.

**Large Power Transformers Transportation** According to the letter of H.J. Stern, the President of NORCA Machinery Corporation, Empire State Building 350 5th Avenue, N.Y., dated December 11 1974, A. D. Dimarogonas performed a thorough structural analysis to verify and substantiate design calculations for a 500 ton railroad car built by the company in Europe. Transporting Large Power Transformers (LPT) is challenging—its large dimensions and heavy weight pose unique requirements to ensure safe and efficient transportation. At that time, specialized railroad freight cars known as the Schnabel railcars used to transport extremely heavy loads, and to accommodate height via railways, were few available worldwide, and 300 ton maximum capacity. In 1973 Swedish electrical-equipment maker ASEA out-Schnabeled its US counterparts, placing in service a 32 axle, 500 ton capacity railroad car that gains world record acclaim for its 240-ft length, design and built from NORCA Machinery Corp., and assembled in Sweden (*Electrical World*, Sept. 1 1973, pp. 95–96) (Fig. 20).

The new transporter is basically a Schnabel Car, but of a new and unusual design, the load is supported within a girder system, than by its two end sections in previous designs. Thus, the transformer carried by the new system is not subjected to compression and tension stresses, and its construction can be lighter, leading in weight—saving for both the transformer and the car. The upper structure of the car can be shifted laterally by 22 in. and lifted vertically by 24 in. with the aid of a hydraulic system, in order to avoid obstacles, station platforms, bridges or sharp curves. Dimensions and axle loading for the car were selected to conform to European railroad load maximums of 44,000 lb/axle.

**Automotive Design** Professor Dimarogonas has contributed in the design and development of a small two-seater city car. The project launched at the Machine Design Lab of the University of Patras in 1986. The authors undertook the major part of the design and development of the project and the progress of this work is published in a series of SAE papers in the 1990s. The intention of the development of E-240 Rio, the mini-car of the University of Patras, was to combine the design of a functional, good-looking, small city car and the development of the required design and manufacturing tools and assembly practices. The mini car design and assembly and field tests were completed early in 1992 (Chondros et al. 1994, 1997c, d, 1998, 2001; Papadimitropoulos et al. 1999; Kalogirou et al. 2000, 2002). Stylist's free-hand sketches for the small city-car trademarked *Rio*, from the neighboring village Rio and the famous Rio-Andirio bridge, then under design, are shown in Fig. 21.

A computer-aided design algorithm was developed for the selection of the exterior and interior main dimensions, wheelbase, total length, height, width, and other dimensions necessary for the design process, according to the seating reference point (ISO 6549) and the limitations imposed by defining the positions of the eyellipse (SAE J941) and the eye points (RREG 77/649). This procedure led to the development of a testing prototype and a body model (Fig. 21). On November 4 1992 the Rio mini car project testing prototype was completed and presented in a Public Hearing of the Transport and Tourism Commission of the European Parliament in Brussels (Fig. 21) (Chondros et al. 1994, 1997c, d, 1998, 2001; Papadimitropoulos et al. 1999; Kalogirou et al. 2000, 2002).

Automotive design is mentioned extensively in Prof Dimarogonas work, and associated issues were taught in class as well as students assignments on design, structural and dynamic behavior were addressed. Form and function is discussed along with the concurrent engineering process taking place today almost exclusively

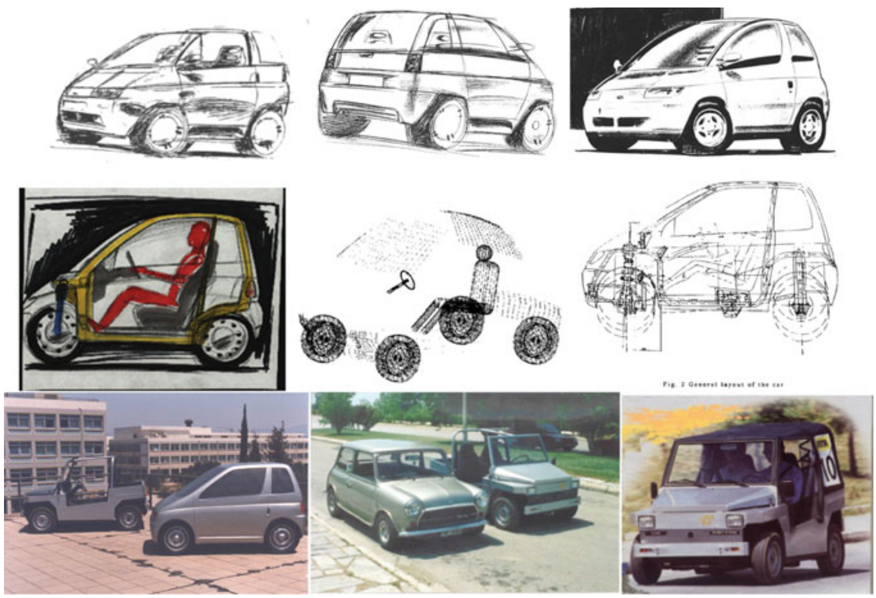

**Fig. 21** Stylist's Dimitri Spanos, free-hand sketches of the mini city car Rio in 1990, the 3D model, the testing prototype and the car body model

in automotive industry. Dimarogonas states that the relationship between form and function has narrowed in a period of equilibrium between aesthetic and functional needs. The sophistication of modern technologies leads to truly worthwhile aesthetic achievements with the motor car design field providing favoring functional-utilitarian solutions.

According to Prof. Dimarogonas the final philosophical question on engineering design and artistic creativity will always remain, since artistic products are based on the work of just one or two people and the resources they need to express their art, however although much technological sophistication is deployed in engineering, it will never be comparable with artistic creativity, as the major contribution comes from the mind, eye, and hand. The tradition in automotive design continues at the Mechanical Engineering Department in the University of Patras through collaboration programs with the automotive industry.

## 3 Epilogue

Professor Dimarogonas was an imaginative and thorough engineer who has contributed in the development of the Design Theory, Vibration, Biomechanics and the History of Technology, integrating industry and academia with a rigid adherence to mathematical rigor. His works incorporate machine development, along with economic and social development, the relationship of technology to politics, economics, science, the arts, the way society shapes science and technology, and the way science and technology shape society and the environment. He was the founder of the Greek IFToMM National Committee in the 80s. His books on computer-aided machine design and vibration for engineers won him international acclaim as a leading expert in the field of mechanical design. He received the 1999 ASME Engineer-Historian Award for his many works on integrating the history of mechanical engineering. His books and published works contain important design paradigms, incorporating machines and systems with a large degree of automation aided by the classical theory of applied mechanics and control. He had tremendous depth of understanding of the physical phenomena involved, of their analytical modeling and also in corroborating techniques of numerical analysis.

In his works different and new approaches and requirements are synthesized and evaluated in the areas of the Theory of Machines Design and Vibrations. In his research he brought about innovative developments in the areas of heat transfer, of rotor dynamics, of thermoelasticity, of structural dynamics and vibration analysis, friction, wear, clearances, lubrication, elasticity, damping, acoustics and noise control, and diagnostics, along with mathematical analysis, computer modeling and simulation, experimental prototyping and testing, and by extrapolating information from past experience, and practical applications. He sugested a new generalization of a technique for the kinematic synthesis of geared multi-link mechanisms, presented in the 11th ASME Conference held in Colombus Ohio in 1971, and in his lectures to graduate classes afterwards. He had a natural gift and great talent as a teacher, and a unique ability to impart knowledge in a class of students consisting of full-time graduate students, as well as participating engineerstaking part-time courses towards advanced degrees.

Prof. Dimarogonas had a unique ability to combine information and techniques from several technical dsciplines in practical design situations. He did original work with almost all areas of design of steam and gas turnines including stres analysis, creep, low cycle fatigue, rotor dynamics—synchronous and asynchronous—oil film bearing design, blade vibrations, thermodymamics, steam cycles, structural dynamics and controls—both mehanical and electro-hydraulic. This expertise has resulted in the design and development of specific instruments, devices and machines, some of them patented already. The software available in the *CAD for Engineers* book provides the readers with the capability of producing their own vibration monitoring device with a portable PC, a junction board, a testing hammer, and some accelerometers. An Expert system is also available for enhancing the device operation. The CAD software also available in the *CAD for Engineers* book is a powerful design tool both for graduate students and practicing engineers.

Analysis being an integral part of design in Dimarogonas' books has been incorporated with the theory of mechanisms, artificial intelligence, and mathematical modeling. Computation considered today a third pillar to the classical two pillars of the scientific method is thoroughly integrated to theory and experiment in the work of Dimarogonas, a significant achievement in the field of engineering education that is delivered to future generations through his work.

Dimarogonas works encompassing a wide variety of engineering disciplines provide considerable contribution to the development of Engineering Education and the History of Tecgnology (Dimarogonas 1976b, 1978b, 1982, 1984b, 1990c, d, 1992c, d, e, 1994c, 1995a, b, c, 1993b, c, d, e, 1997c; Dimarogonas and Chondros 1997), Engineering Design and Kinematics (Dimarogonas et al. 1971, 1992; Dimarogonas 1971a, b, c, e, f, 1981a, b, 1983, 1984a, 1987, 1988b; Dimarogonas and Sandor 1971; Dimarogonas and Maniatis 1976; Dimarogonas and Barman 1977; Dimarogonas and Massouros 1979b; Dimarogonas and Mourikis 1980; Panteliou et al. 1987, 1988; Chondros et al. 1987; Dimarogonas and Nakamura 1993; Panteliou et al. 1989; 1990, 1998; Kollias and Dimarogonas 1992b; Yiannopoulos et al. 1997), Friction and Wear (Theophanopoulos and Dimarogonas 1967; Dimarogonas 1969, 1973e, f; Masouros et al. 1977, 1979; Dimarogonas and Massouros 1979a, Dimarogonas and Michalopoulos 1981; Michalopoulos and Dimarogonas 1981, 1982; Massouros and Dimarogonas 1986; Michalopoulos et al. 1986; Andritsos and Dimarogonas 1986; Dimarogonas 1987c, 1988c; Dimarogonas and Kollias 1989, 1992b; Kollias and Dimarogonas 1993a, b; Anifantis and Dimarogonas 1993), Rotor Dynamics, Turbomachinery and Heat Propagation (Dimarogonas 1971b, 1972a, b, 1973b, c, d, 1974a, b, 1975, 1977b, 1983a; Kounas et al. 1972; Dimarogonas and Sandor 1973; Panteliou and Dimarogonas 1980, 1981a, b; Aspragathos and Dimarogonas 1982b; Panteliou and Dimarogonas 1982, 1983; Panteliou et al. 1983; Dimarogonas 1985a, b, 1986d, 1990a, b, f; Gomez-Mancilla and Dimarogonas 1992a, 1992b;

Dimarogonas and Kollias 1992a, c; Kollias and Dimarogonas 1992a, 1994; Dimarogonas 1992a, h, 1993f, g, h, i, 1994b; Dimarogonas and Kollias 1993a, b; Gomez-Mancilla and Dimarogonas 1993a, b; Dimarogonas and Gómez-Mancilla 1994, 1996; Gómez-Mancilla and Dimarogonas 1995, 1996; Panussis and Dimarogonas 1997, 2000), Structural Dynamics, Damping, Fatigue and Crack Identification (Chondros and Dimarogonas 1979, 1980; Aspragathos and Dimarogonas 1980; Andritsos and Dimarogonas 1980; Dimarogonas 1981c, d, 1994a; Dimarogonas and Massouros 1981; Aspragathos and Dimarogonas 1982a; Anifantis et al. 1982, 1983; Anifantis and Dimarogonas 1983a, b, c; Anifantis 1983c; Dentsoras 1983a, b, c; Aspragathos and Dimarogonas 1983, 1984; Anifantis and Dimarogonas 1984; Dimarogonas 1987a; Michalopoulos et al. 1987; Papadopoulos and Dimarogonas 1987a, b, c, d, 1992; Nikpur and Dimarogonas 1988; Dimarogonas and Papadopoulos 1988, 1990; Yao and Dimarogonas 1988; Rizos and Dimarogonas 1988; Gounaris and Dimarogonas 1988; Papaeconomou and Dimarogonas 1989; Chondros and Dimarogonas 1989; Dentsoras and Dimarogonas 1989; Actis and Dimarogonas 1989; Rizos et al. 1990; Gounaris et al. 1991; Dimarogonas 1992b, g; Dimarogonas and Syrimbeis 1992; Anifantis et al. 1994; Dimarogonas 1995d, e, 1996; Gounaris et al. 1996; Chondros et al. 1997a, b; Chondros and Dimarogonas 1998; Chondros et al. 1998a, b, c; Panteliou and Dimarogonas 2000a, b; Panteliou et al. 2001), Automotive Design (Chondros et al. 1994, 1997c, d, 1998, 2001; Papadimitropoulos et al. 1999; Kalogirou et al. 2000, 2002), Bioengineering (Nikiforidis et al. 1986, 1990; Dimarogonas et al. 1993; Dimarogonas 1993j; Civitelli et al. 1995; Panteliou et al. 1995a, b, 1996, 1999; Panteliou and Dimarogonas 1996, 1997a, b; Armamento-Villarea et al. 1997), Vibration Engineering, Tribology and Lubrication, the Theory of Machines and Engineering Education and Ethics, along with the IFToMM aim and scope for promoting the integration of engineering science into the international community in industry and the Academia.

A list of Prof. Dimarogonas main works and continuing work in chronological order follows.

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Dimarogonas AD (1997a) Method and apparatus for predicting structural integrity by estimating modal damping factor. Patent No 5,652,386. June 7, 1997a. International Patents pending
Dimarogonas AD (1997b) Method and apparatus for predicting fatigue by introducing a continuous excitation to determine damping factor. Patent No 5,614,674. June 7, 1997b. International Patents pending
Dimarogonas AD Automatic re-bar bending machine (OBI Greek Patent Organization)
Dimarogonas AD Combination antifreeze air blower/windmill generator (OBI Greek Patent Organization)
Dimarogonas AD Automatically closing packing for turbine Rotors (Assigned to General Electric Co.)

## *Major Addresses*

126th Meeting of the acoustical society of America, Denver Colorado, October 1993. Acoustic and vibration monitoring of rotating machinery. Plenary lecture

1993 ASME design engineering conferences, Albuquerque, NM. The origins of engineering design, Plenary lecture

2nd lnternational sound and vibration conference, June 21–27, Beijing, China. Vibration of cracked structures. Opening address

Artificial intelligence conference, Cuernavaca, Mexico (1992) Diagnosis and prognosis of machinery failures, keynote address

ASME 2nd Biennial European conference on engineering systems design and analysis, July 4–7, Lonon, England. Macro-ethics in engineering design. keynote address

City Hall, Nikaia, Greece (1978) The Helsinki Accord for the European Cooperation

City of Agrinion, Central Square, Greece (1977) Towards a new Era for Greece

Municipal Theater of Patras, Greece (1977) New challenges for the hellenic youth

Rotordynamics 92 (Intern Conf), Venice (1991) A brief history of rotor dynamics, keynote address

Springer Lecture, University of California-Berkeley (November 1993) interval analysis of mechanical systems

St. Louis Research Council (1992) Machinery of the ancient Greek theater, keynote lecture

University of Patras, main auditorium, Greece (1979) The Ideological Preparation of the Greek Revolution of 1821, keynote address

## *Selected Papers*

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# Veniamin Goldfarb (1941–2019)

**Evgenii Trubachev and Natalya Barmina**

**Abstract** This paper considers the contribution to MMS of the world-known Russian gear scientists and active organizer and participant of various scientific events Professor Veniamin Goldfarb (1941–2019). In spite of his medical scientific ancestry, Veniamin Goldfarb became a Dr. Sc. in Engineering and Full Professor of Kalashnikov Izhevsk State Technical University. His way of becoming a scientist, organizing his own scientific school, foundation of the Institute of Mechanics as a scientific department of Kalashnikov Izhevsk State Technical University, starting a unique for Russia scientific production enterprise "Mechanik", and his multifaceted university activity with his publications and patents are of great interest from historical point of view. His educational and international activity—editing and publishing efforts—contributed much to promoting the integration of the Russian gearing science into the international community, and to all-Russian and international cooperation in the field of MMS, especially in gears and transmissions in the second half of the XX century. In this manuscript we would also like to describe in details the scientific achievements and legacy left by Professor Veniamin Goldfarb.

## 1 Biographical Notes

Professor Veniamin Goldfarb (Fig. 1) was a Doctor of Technical Sciences, Professor, Honored Scientist of the Russian Federation, Director of the Scientific department "Institute of Mechanics" of Kalashnikov Izhevsk State Technical University, member of the International Federation for the Promotion of Mechanism and Machine Science (IFToMM), Chairman of the Technical Committee for Gearing and Transmissions from 1998 to 2005, member of the Executive Council from 2007 to 2011, Vice President of the Federation from 2011 to 2015, member of the International Organization for Standardization (ISO), Honorary Member of the Slovak Union of Mechanical

E. Trubachev · N. Barmina (✉)
Scientific department, "Institute of Mechanics Named After Professor V. I. Goldfarb", Kalashnikov Izhevsk State Technical University, Izhevsk, Russia
e-mail: barmina-nat@mail.ru



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**Fig. 1** Professor Veniamin Goldfarb

Engineers and the Bulgarian Union of Mechanical Engineers, New York Academy of Sciences, Academician of the International Informatization Academy and the Russian Academy of Natural Sciences. Professor Veniamin Goldfarb was the Prize winner of the State Prize in the field of science and technology, Honorary Worker of Higher Professional Education of the Russian Federation, Honorary Professor of ISTU. He was awarded the Medal of Academician V. I. Vernadsky, Medal of Academician S. P. Kapitsa “To the author of a scientific invention” by the St. George Cross of the Russian Academy of Natural Sciences and the medal “Inventor of the USSR” for his merits in economics and science.

Prof. V. I. Goldfarb was the author of more than 300 scientific publications, including 10 monographs in the field of research, development and implementation of gears. The complete list of his publications is given in References. For more than a quarter of a century, he led a scientific school “Institute of Mechanics”—the creative community of talented and successful, young scientists, where 16 Dr. Sc. and 38 Ph.D. theses were completed, more than 30 patents of the USSR and Russian Federation were obtained. He was a supervisor of 16 Ph.D. students and consulted 5 Doctors of Science. A large number of gear scientists from other scientific schools got the support of Professor Goldfarb.

Veniamin Iosifovich Goldfarb was born on February 01, 1941 in Izhevsk (Russia) in the family of medical doctors. But he chose to become an engineer and in 1962 he graduated from the Department of Instrument Design of Izhevsk Mechanical

Institute—IMI (now Kalashnikov Izhevsk State Technical University—ISTU. The issues of instruments and everything connected with them, including computers and their programming were not just popular, but super popular that time. The future professor Veniamin Goldfarb was one of the best and most notable in this community. It should be said that even then he was distinguished not only by his intellect and quick wit—his charisma and leadership qualities were evident to everybody. After graduation in 1962 he started his scientific and educational activity (Fig. 2). Since 1962 till 2019 the university IMI/ISTU was his only affiliation. Veniamin Goldfarb devoted his whole life to this university where he made a respectful career from the assistant, associate professor to the full professor, head of Mechanical Engineering department, director of the scientific department "Institute of Mechanics" and the head of the scientific production enterprise "Mechanik":

1957–1962—Student at Izhevsk Mechanical Institute (now Kalashnikov ISTU).

1962—Assistant of "MMS and Theoretical Mechanics" Department.

1963—Assistant of "Gyroscopic devices" Department.

1965—Senior Lecturer of "Gyroscopic devices" Department.

**Fig. 2** Professor Veniamin Goldfarb (to the right) at the beginning of his educational and scientific career, 1962

1968—Postgraduate course.

1969—Ph.D. thesis on Engineering.

1970—Associate Professor of "Instrumentation parts" Department.

1986—Doctor of Engineering Science thesis.

1987—Professor of "Devices and methods of quality control" Department.

1991—Professor of "Technology of robotized production" Department.

1994–2019—Head of the newly organized scientific department "Institute of Mechanics".

1995–2014—Head of "Design and manufacturing preparation of mechanical engineering production" Department (Fig. 3).

2014–2016—Professor of "Design and manufacturing preparation of mechanical engineering production" Department.

The MMS community knows Professor Veniamin Goldfarb mostly for his activity in 2000–2015 mainly within IFToMM—as a Gearing TC member and Chair and then IFToMM Vice-President. He had an exciting diversified life of the scientist and active leader with a wide range of interests, skills and events. His ancestry, his way of becoming a scientist, organizing his own scientific school, foundation of the Institute of Mechanics as a scientific department of Kalashnikov Izhevsk State Technical University, starting a unique for Russia scientific production enterprise "Mechanik", and his multifaceted university activity are fully described in the paper within the book devoted to the memory of professor Goldfarb (Trubachev, E.S., Barmina, N.A., Malina, O. V.: Professor V. I. Goldfarb: Life Activity and Contribution to Gearing Science. In: Gears in Design, Production and Education. A Tribute to Prof. Veniamin Goldfarb Springer International Publishing AG Switzerland. Barmina, Natalya, Trubachev, Evgenii (Eds.). Vol. 101, pp. 1–59. ISBN 978-3-030-73,022-2 (2021). In the paper currently in publication (E. Trubachev, N. Barmina, M. Ceccarelli. Contribution of Professor Veniamin Goldfarb to promotion of gearing science and international cooperation. Proceedings of the 7th International Symposium on History of Machines and Mechanisms, Spain, Granada, 2022) the authors considered mainly his educational and international activity – editing and publishing efforts, promoting the integration of the Russian gearing science into the international community, and his contribution to all-Russian and international cooperation in the field of MMS, especially in gears and transmissions. In this paper we would like to describe in details the scientific achievements and legacy left by Professor Veniamin Goldfarb with the complete list of his publications for the period of 1964–2019 (Goldfarb and Tkachev 1997, 1999, 2003, 2004a, 2005a, b, 2006, 2007, 2008, 2011; Goldfarb et al. 1975, 1976, 1982, 1983a, b, 1984, 1987, 1989a, b, c, d, 1990, 1991a, b, c, 1993a, b, c, d, e, f, 1994a, b, c, d, e, f, g, h, i, 1995a, b, c, d, e, f, 1996a, b, c, d, 1997a, b, c, d, e, f, 1998a, b, c, d, e, f, 1999a, b, c, d, 2000a, b, c, e, 2001, 2002, 2003a, b, 2004a, b, 2005a, b, c, c, 2006a, 2006b, 2006c, 2006d, 2007a, b, 2008a, b, c, d, e, 2009b, c, d, e, 2010, 2011a, b, c, d, e, 2012, 2013a, b, c, 2014a, b, c, 2015a, b, c, d, 2016a, b, 2017, 2018, 2019a, b, c; Starzhinsky et al. 2011, 2017a, b; Antonyuk et al. 2012; Georgiev et al. 1974, 1975, 1976, 1977, 1978; Goldfarb 1993a, 1993b, 1994a, b, 1995a, b, c, d, 1996, 1997a, b, 1998a, b, c, d, e, 1999, 2000a, b, c, 2001a, b, c, d, 2002, 2005, 2006a, 2008a, b, 2010a, b, 2011a, b, 2012, 2013a, b, 2014a, b, 2015, 2016, 2017a, b, 2021; Plekhanov and Goldfarb 2014, 2016, 2019; Plekhanov et al. 2018; Starzhinsky et al. 2014, 2017c, d; Goldfarb and Barmina 2003, 2013; Goldfarb and Anferov 1992, 1999, 2000, 2012; Tkachev et al. 2012; Koroleva et al. 2012; Makarov et al. 2010; Goldfarb and Trubachev 2001a, b, 2002a, b, 2004, 2007, 2008, 2010; Goldfarb and Karakulov 2010a, b; Tkachev and Goldfarb 2009a, b; Goldfarb and Glavatskikh 1996, 2009; Goldfarb and Pichugin 2006, 2007; Popova and Goldfarb 2006; Goldfarb and Makarov 2005; Goldfarb and Lunin 2004; Herzenstein et al. 2004; Goldfarb and Kuniver 2003; Goldfarb and Popova 2003; Trubachev and Goldfarb 2001; Goldfarb and Airapetov 1998, 2000; Goldfarb and Voznyuk 1998, 2000; Goldfarb and YeS 1997b, 2000d; Goldfarb and Malina 1990, 1991, 1993, 1999a, b; Goldfarb and Koshkin 1999; Goldfarb and Mokretsov 1998; Goldfarb and Abramov 1994, 1996a, b, 1997, 1998; Goldfarb and Spiridonov 1994, 1996, 1997; Goldfarb and Russkikh 1991a, b, 1992, 1997; Goldfarb and Mudrik 1996; Goldfarb and Isakova 1992, 1993, 1994a, b, 1995; Goldfarb and Mardanov 1990a, b, 1994; Goldfarb and Koryakin 1992, 1993, 1994; Goldfarb and Kuniver 1993; Goldfarb and Oleksiuk 1993; Goldfarb 1969a, 1968, 1971, 1972, 1976a, b, c, 1977, 1983, 1984, 1985a, b, 1987, 1989a, b, c, 1990a, b, 1991a, b, c, d, 1993c; Goldfarb and Kulemin 1990a, b; Goldfarb and Koroleva 1989, 1990; Chekalkin et al. 1989; Goldfarb and Trubitsyn 1985; Goldfarb and Zlatkin 1985; Goldfarb and Nesmelov 1977, 1979a, b, 1980, 1981, 1982a, b, c, 1983, 1984; Nesmelov and Goldfarb 1976, 1983; Goldfarb and Long 1982; Goldfarb and Anikin 1981; Georgiev and Goldfarb 1972a, b, 1974, 1975, 1978; Goldfarb and Ezerskaya 1975; Goldfarb and Georgiev 1967, 1971a; Yastrebov and Goldfarb 1964a) (Fig. 3).

## 2 List of Main Works

1. Yastrebov, V. M., Goldfarb, V. I.: Tables of coordinates of curvature radii and radii-vectors of involute points for gearwheels with tooth numbers from 12 to 120 (1964).
2. Goldfarb, V. I.: Research of a variety of the orthogonal hypoid worm (spiroid) gear with a cylindrical worm: Thesis of Candidate of Technical Sciences (PhD in Engineering) (1969).
3. Goldfarb, V. I., Georgiev, A. K.: Aspects of geometrical theory and research results for spiroid gears with cylindrical worms (1971).
4. Georgiev, A. K., Goldfarb, V. I., Rud, L. V.: Russian State Standard GOST 22,850–77. Spiroid gears. Terms, definitions and designations (1977).
5. Goldfarb, V. I.: Fundamentals of the theory of computer-aided geometrical analysis and synthesis of general type worm gears: Thesis of Doctor of Technical Sciences (Dr. Sc. in Engineering) (1985).

**Fig. 3** Professor Veniamin Goldfarb (in the centre, low row) is the head of "Design and manufacturing preparation of mechanical engineering production" Department, Kalashnikov Izhevsk State Technical University, 2005

6. Goldfarb, V. I., Lunin, S. V., Trubachev, E. S.: Direct digital simulation for gears. Vol. 1, Izhevsk, ISTU (2004).
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10. Goldfarb, V. I., Anferov, V. N., Glavatskikh, D. V., Trubachev, E. S.: Spiroid gearboxes for operation in extreme conditions (2014).
11. Goldfarb, V.: Some Exercises with equations of meshing: review of fundamental manuscript. In: Gears in Design, Production and Education. A Tribute to Prof. Veniamin Goldfarb. Springer International Publishing AG Switzerland. Barmina, Natalya, Trubachev, Evgenii (Eds.). Vol. 101, pp. 61–68. ISBN 978–3-030–73,022-2 (2021).

## 3 Review of Main Works

The main scientific interests of Professor Veniamin Goldfarb were in the field MMS-related areas including theory of gearing, and theory and practice of design, manufacture, testing and application of worm-type gears, gearboxes, and gearmotors (Goldfarb et al. 2011a). Being a graduate of the Instrumentation engineering department, Professor Goldfarb introduced CAD into gear research in the early 1970s which was a new trend and unstudied area in the USSR that time. In 1980 he began to form his own scientific school at his Instrument Design Department. Perhaps, one of findings of that time was the form of organization of this school—as a Student Design Bureau of the Instrument Design Department. It was named “Student Design Bureau of Gears” first among the students and then officially; many promising students got “scientific trial by fire” there. Hundreds of students’ term and graduation projects and scientific research works carried out under the supervision of V. I. Goldfarb made it possible to polish both his methods of work with students and his own new methods of calculation. The basis for their proposal and development was the experience of solving complex geometrical problems obtained in the 1960s and 1970s.

Among these methods, the “non-differential method” of calculating the generated and meshing surfaces proposed jointly with Eng. I. P. Nesmelov (Nesmelov and Goldfarb 1983) is of a special importance (Fig. 4). V. I. Goldfarb is one of the founders of the currently prevailing non-differential methods for studying gears (see, in particular, the classical work (Nesmelov and Goldfarb 1983) or a more recent paper by Goldfarb V. I. 1995b). Another fundamental publication on the results of this scientific research (Goldfarb 2001a) had a very limited number, and not everybody had a chance to read it. That was why, it was republished (Goldfarb 2021) with comments by Prof. Evgenii Trubachev and Dr. Sergey Lagutin. The manuscript (Goldfarb 2021) describes the history of solving one of the fundamental questions in the theory of gearing—the question about the search for generated and meshing

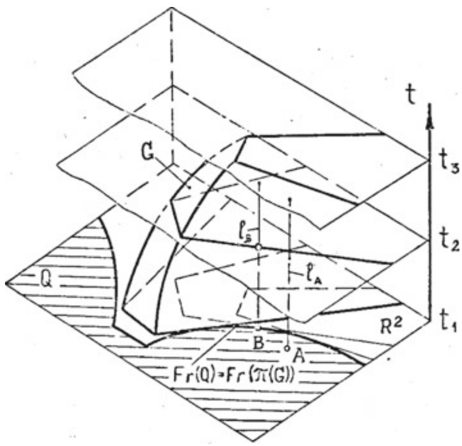


**Fig. 4** Scheme of “non-differential method” (fragment from Doctor of Science Thesis by V. I. Goldfarb

surfaces of teeth, the question about the "equation of meshing", different versions of its representation and their application for solving the problems of gear analysis and synthesis are considered. And it is therefore more interesting for the reader to get acquainted with his evaluation of analytical methods of gearing research. Besides, in our opinion, the importance of this work is to summarize the efforts of the scientists who worked on the methods of searching for enveloping surfaces in different fields—basically higher and differential geometry (to which the question goes back), theory of gearing, theory of generating, and theory of cutting tools. Although the question of fundamental methods for calculating the meshing surfaces in the modern theory of gearing and theory of generating is, as we see it, solved with the exhaustive completeness for common applications, the generalization made by Prof. Goldfarb finding general theoretical assumptions, concepts and regularities, in our opinion, serves to better modern understanding of this issue. We also see the great educational value of the published manuscript,it is of fundamental importance and allows the contemporaries who apply and improve numerical methods of simulation not to lose sight of the very essence of the meshing process. Let us also pay attention to the fact that although Prof. V. I. Goldfarb stipulated the case of meshing of two gear elements rotating relative to their stationary axes at the very beginning, in principle the approach and all calculations are easily extended to more general cases of meshing and generating, including processes with other motions and multiple coordinate transformations—to those cases which are reduced to the enveloping process of one-parameter families of surfaces.

The second major part of V. I. Goldfarb research in the early 1980s was related to studies of spatial gearing schemes and aimed at predicting the principal properties of gears at the early stage of design: dimensions and shape of elements, direction and character of tooth contact (internal or external). The following general solutions for arbitrary arrangement of axes and shapes of elements were obtained:

- condition for contact of initial surfaces;
- areas of gear scheme existence;
- conditions for determining the type of contact—internal or external;
- condition for choosing a preferred ratio of directions for rotation of elements.

Prof. V. I. Goldfarb classification (Goldfarb and Malina 1999b) included gears with:

- bevel and inverse conical elements;
- one flat element;
- one cylindrical element;
- internal meshing with respect to each of the elements.

The number of variants turns out to be one order greater in schemes of two-stage gears (Goldfarb and Malina 1999a). Here are other interesting schematic solutions obtained by V. I. Goldfarb of course, this is only a small part of the proposed solutions):

- gear with ideal-constant helical parameter (axial pitch) of a pinion (worm) (Goldfarb 1976b);

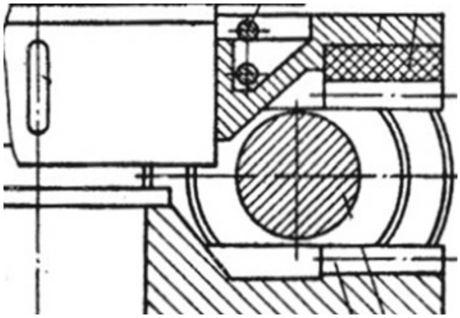

**Fig. 5** Spiroid gear with rotaprint lubrication of meshing (the lubricating gearwheel is above the worm, the operating one is below)

- gear with rotaprint lubrication (Goldfarb and Anferov 2012) (self-lubricating gear—in co-authorship with Prof. V. N. Anferov)—Fig. 5;
- worm type gear with internal meshing relative to the worm—Goldfarb V. I., Russkikh, A. G., Trubachev, E. S.: Internal gear with intersecting axes. Patent of Russia №2,101,582 dated 10.01.98—Fig. 6,
- non-orthogonal gear with two meshing zones—Goldfarb V. I., Nesmelov, I. P.: Non-orthogonal gear transmission with intersecting axes. Author's certificate №806,935, dated 23.02.81, bul. No 7—Fig. 7.

The third important scientific problem solved by V. I. Goldfarb in 1980s was the generalization of the approach to computer-aided design of the conjugate worm-type gear. The main result is a reasonable decomposition of this process (Goldfarb 1991b) into stages:

1. Selection of the gear scheme.
2. Calculation of tooth flank geometry.
3. Calculation of geometrical and kinematic contact parameters (sliding velocities, length and arrangement of lines/points of the conjugate contact, reduced radii of curvature, velocities of movement of contact points on the tooth flanks).

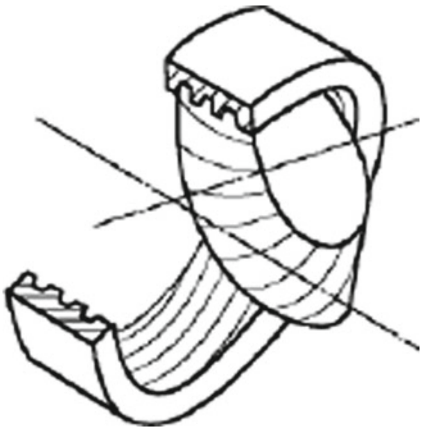

**Fig. 6** Gear with internal meshing relative to the worm

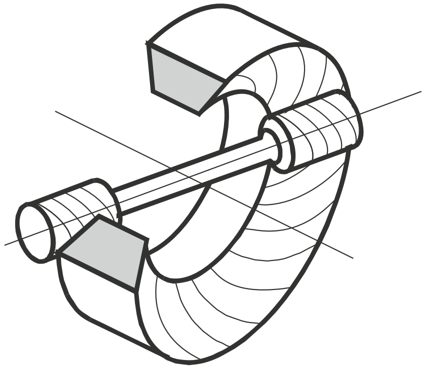

**Fig. 7** Non-orthogonal gear with two meshing zones

4. Evaluation of forces acting in the meshing, efficiency, load-carrying capacity of the gear in accordance with various criteria.

This approach aims to streamline the automated design process, to make it more meaningful for the designer by leading the process "from simple to complex", giving the designer an opportunity to consistently narrow down the multi-dimensional space of parameters and the number of possible and acceptable solutions, to obtain fast gear estimates at early stages, and it allows a designing engineer to rationally arrange the computational procedures and data structures. The sequence was implemented in the first CAD-program for spiroid gears "SPDIAL" developed by Eng. I. P. Nesmelov under the guidance of V. I. Goldfarb in 1980s (Goldfarb and Nesmelov 1982a). The calculation in this program was focused on designing a theoretically accurate conjugate spiroid gear. Later on, the sequence was developed taking into account the problems of real manufacturing and real operation of gears, and it was extended to the cases of worm and bevel gears by V. I. Goldfarb and his pupil, one of the authors of this manuscript, E. S. Trubachev, who implemented it together with his pupils in the new software complex CAD system "SPDIAL+" in the period from 1996 to the present (Goldfarb and Trubachev 2002b).

The mentioned three parts of V. I. Goldfarb scientific developments became the basis for his DSc Thesis "Fundamentals of the theory of automated geometrical analysis and synthesis of general type worm gears", which was presented in 1986.

The multifaceted scientific research in the field of gear schemes and their practical implementation also resulted in a great number of USS, Russian and international patents and author's certificates for inventions and useful models received by Professor Goldfarb and his colleague during his long scientific activity period:

1. Goldfarb, V. I., Georgiev, A. K.: Gear with intersecting axes. Author's certificate No 208396 dated 16.10.67.
2. Goldfarb, V. I., Georgiev, A. K.: Ortogonal skew axis gearing. Patent of England No 1359550 dated 16.12.71.
3. Goldfarb, V. I., Georgiev, A. K.: Ingranaggio ortogonale con assi incrociati. Patent of Italy No 949487 dated 20.01.72.

4. Goldfarb, V. I., Georgiev, A. K.: Transmissio ortogonale an engrenage a axec entrecroises. Patent of France N2166643 dated 23.08.73.
5. Goldfarb, V. I., Georgiev, A. K.: Orthogonal skew-axis gearing. Patent of the USA No 3768326 dated 30.10.73.
6. Goldfarb, V. I., Georgiev, A. K.: Orthogonale nonintersecting axis gearing. - Patent of Canada No 954340 dated 10.09.74.
7. Goldfarb, V. I., Georgiev, A. K.: Ortogonal skew axis gearing. Planskruvvaxel. Swedish Patent No 361346 dated 7.02.74.
8. Goldfarb, V. I., Georgiev, A. K.: Orthogonales Radgetriebe. Patent of Germany No 2161666 dated 7.08.75.
9. Goldfarb, V. I., Georgiev, A. K.: Orthogonale nonintersecting axis gearing. Orthogonale skew-axis gearing. Patent of Japan No 5125894 dated 3.08.76.
10. Goldfarb, V. I., Nikitin, A. S., Nesmelov, I. P.: Double-stage gearbox. Author's certificate No 875133 dated 23.10.81, bul. N39.
11. Goldfarb, V. I., Nesmelov, I. P.: Non-orthogonal gear transmission with intersecting axes. Author's certificate No 806935, dated 23.02.81, bul. No 7.
12. Goldfarb, V. I., Nesmelov, I. P., Chistyakov, D. E.: Double-stage gearbox. Author's certificate No 973973 dated 15.11.82, bul. N42.
13. Goldfarb, V. I., Nesmelov, I. P., Teterin, A. N.: Double-rim gear with intersecting axes. Author's certificate No 1059325 dated 7.12.83, bul. N45.
14. Goldfarb, V. I., Solovyov, B. M., Savin, M. N., Gilfanov, R. M.: Device for the precise displacement of the machine-tool working part. - Author's certificate No 1199461 dated 23.12.85, bul. N47.
15. Goldfarb, V. I., Chekalkin, G. T., Lagutin, S. A., Borilo, A. M., Galkin, N. I.: Device for control of longitudinal line of gearwheel teeth. Author's certificate No 1237896 dated 15.06.86, bul. N22.
16. Goldfarb, V. I., Lagutin, S. A., Kovtushenko, A. A., Verkhovsky, A. V.: Method of cutting the worm cylindrical gearwheel teeth. Author's certificate N1231717 dated 15.01.86.
17. Goldfarb, V. I., Mardanov, I. I.: Non-orthogonal tooth gear with intersecting axes. Author's certificate No 1421912 dated 7.09.88, bul. No 33.
18. Goldfarb, V. I., Kuniver, A. S., Chekalkin, G. T.: Assembled gear wheel. Author's certificate No 1744351 dated 30.06.92, bul. No 24.
19. Goldfarb, V. I., Kuniver, A. S.: Cylindrical spiroid hob. Patent of Russia No 2095204 dated 10.10.97.
20. Goldfarb, V. I., Osetrov, V. G., Mokretsov, V. N., Kuniver, A. S.: Ball worm gear. Patent of Russia No 2092726 dated 10.10.97.
21. Goldfarb, V. I., Plekhanov, F. I., Mokretsov, V. N., Spiridonov, V. M.: Planetary gear. Patent of Russia No 2092727 dated 10.10.97.
22. Goldfarb, V. I., Russkikh, A. G., Trubachev, E. S.: Internal gear with intersecting axes. Patent of Russia No 2101582 dated 10.01.98.
23. Goldfarb, V. I., Makarov, V. V., Gromov, D. P., Trubachev, E. S., Kuznetsov, A. S., Fedin, S. A., Shanaurin, A. L.: Drive for stop and regulating valves. Patent of Russia N46066 U1 dated 10.06.2006.

24. Anferov, V. N., Goldfarb, V. I., Kovalkov, A. A.: Spiroid gear with rotaprint gear lubrication. Patent of Russia No 2306465 C2 dated 20.09.2007.
25. Goldfarb, V. I., Gromov, D. P., Trubachev, E. S., Kuznetsov, A. S., Makarov, V. V., Shanaurin, A. L.: Double-speed manual drive for pipeline valves. Patent of Russia No 2343329 C2 dated 10.01.2009.
26. Goldfarb, V. I., Gromov, D. P., Trubachev, E. S., Kuznetsov, A. S., Makarov, V. V.: Double-speed manual drive for pipeline valves. Patent of Russia N2454590 C2 dated 27.06.2012.
27. Plekhanov, F. I., Goldfarb, V. I.: Planetary gear. Patent of Russia N2460916 C1 dated 10.09.2012.

## 4 On the Circulation of Works

In 1960s, still being a student, Veniamin Goldfarb attracted the attention of the already known by that time gearing scientist (specialized in planetary gears) Professor V. M. Yastrebov. He proposed to make a large series of computer calculations of coordinates of points of ordinary involutes of circumferences. Nowadays this task seems trivial, but at that time the issue was so actual for industry (mainly, for gear control purposes) that a book with the results of the calculations was published by a central Moscow publishing house (Yastrebov and Goldfarb 1964a). For those days it was a great achievement, especially for a student.

Another fundamental contribution to the development of gearing science in Russia was participation of Veniamin Goldfarb in the development of the USSR State Standard "Spiroid gears. Terms, definitions and designations" in 1977 (Georgiev et al. 1977). This standard established the terms, definitions and designations used in science, technology and production related to geometry and kinematics of spiroid gears with a constant transmission ratio and 90° crossing angle of the worm and wheel axes. The standard was developed taking into account the recommendation of ISO R 701. The standard provided rules for construction of terms, definitions and designations of spiroid concepts.

As you can see form the list of the referred publications, professor Goldfarb generously shared his knowledge with his students, post-graduates and involved his colleagues from ISTU and other universities into the joint collaboration. That is why almost all his fundamental achievements and publications on the scientific results were co-authored with a great number of other gear scientists.

The book authored by Goldfarb V. I. and Tkachev, A. A. "Design of involute spur gears. New approach" (Fig. 8a) was published in Russian in 2004 (Goldfarb and Tkachev 2004a). It proposed the non-traditional approach to design of involute spur and helical gears on the base of so-called dynamic blocking contours which allowed to choose shift coefficients values for a pinion and a gearwheel, providing required extreme properties of a gear set. The proposed approach was illustrated by design examples with the help of a specially developed computer system "Contour".


**Fig. 8** Books published by Professor Goldfarb with co-authors

The book by Goldfarb V. I., Lunin S. V., and Trubachev E. S. “Direct digital simulation for gears” (Fig. 8b) was also published in 2004 (Goldfarb et al. 2004a). It was a joint research with the American gear scientist Stepan Lunin and it presented a generalization of modern approaches to computer-aided gear design, starting from the general structure of the tasks of this process, general requirements to its organization, methods of solving these tasks, up to the features of its implementation both in specialized programs and universal CAD systems. A special place in the monograph was given to non-differential calculation method or, in other terms, to DDS-method (Direct Digital Simulation). The book was illustrated by numerous examples of implementing the approaches in the design of various types of gears.

The most fundamental book edited and partly written by professor Goldfarb was the summary of more than 40-year experience accumulated in the process of research, design, technological and production-implementation works at the Izhevsk Mechanical Institute: Goldfarb V. I., Glavatskikh, D. V., Trubachev, E. S., Kuznetsov, A. S., Lukin, E. V., Ivanov, D. E., Puzanov, V. Yu.: Spiroid gears for pipeline valves (Fig. 8c) (Goldfarb et al. 2011a). A large number of publications (more than 400), devoted to these transmissions, do not give a complete and integral idea of their possibilities, of methods and means of their design, of mechanisms and machines where they found a successful application, of the prospects of their further introduction in various fields of technology. This book paid more attention to the geometrical theory and design of real spiroid gears, general data on their manufacturing technology and experience of their industrial application. It included:

- General information on spiroid gears, where their place among intersecting axis gears is shown, features and merits of geometry and kinematics of their meshing are described, known varieties of spiroid gears;
- Geometrical theory of conjugate, i.e. ideal spiroid gearing, with the basic dependences used in the synthesis of gears;
- Designing a real spiroid meshing, i.e. a meshing taking into account errors of manufacturing and mounting of the gear, deformations and wear of its links, with a general structure for designing real gearing and methods of solving problems at its individual stages;
- Dialogical system for designing spiroid gears with its capabilities and examples of solving design problems.
- Technology of manufacturing spiroid gears, which is the most important component of their production and implementation.
- Layouts of spiroid gears with examples of specific products created using the methods and tools described in the book.

Dozens of Dr. Sc. and Ph. D. theses were prepared and presented under the leadership of Professor V. I. Goldfarb. Their topics covered a broad range of problems related to the theory of gearing, studying the specific gear types, gearboxes and their properties, and software tools for their design:

*Dr. Sc. in Engineering*:

1. Kuniver, A. S.: Theoretical fundamental of the meshing synthesis for modified spiroid cylindrical gears (2001).
2. Anferov, V. N.: Development of hoisting-and-transport machine drives based on spiroid gears (2002).
3. Malina, O. V.: Theory and practice of automation of the structural synthesis of the objects and processes using the characterization analysis methods (2002).
4. Trubachev, E. S.: Fundamental of analysis and synthesis of the real spiroid gears (2004).
5. Karakulov, M. N.: Scientific fundamentals of plunger gear design (2012).

*Ph.D. in Engineering*:

1. Anferov, V. N.: Development of a method for calculating the wear lifetime of cylindrical spiroid gears (1988).
2. Kulemin, V. Yu.: Development and study of dynamics of the test bench for rotating rotors with large disbalance (1994).
3. Isakova, E. V.: Development and research of the spiroid gear with ideal helical parameter of the worm (1995).
4. Malina, O. V.: Development of software and mathematical support for computer-aided design of mechanical engineering products (by example of the spiroid gearbox) (1995).
5. Glavatskikh, D. V.: Computer-aided modeling of generating helical surfaces of mechanical engineering products (1997).
6. Abramov, A. I.: Theoretical and experimental research of kinematic accuracy and vibration activity of spiroid gears (1996).
7. Russkikh, A. G.: Computer-aided synthesis of gear schemes with intersecting axes (1997).
8. Trubachev, E. S.: Research of the parameters space for non-orthogonal spiroid gears (1999).
9. Plekhanov, D. F.: Research of geometry and main quality parameters of the unconventional gear with involute-epitrohoid meshing (1999).
10. Vozniuk, R. V.: Instrumental system of modeling the enveloping process (1999).
11. Koshkin, D. V.: Error influence research and geometrical modeling of localized contact in the spiroid gear (1999).
12. Tkachev, A. A.: Development of the dialogue design system for involute cylindrical gears (1999).
13. Lunin, S. V.: Development and research of the computer-aided system of solid-state modeling of gears (2000).
14. Barmina, N. A.: Structural and parametric synthesis of double-stage gearboxes with spiroid and cylindrical gears (2002).
15. Popova, E. I.: Development of tools and technology of generating the metal polymeric spiroid gearwheels (2004).
16. Lukin, E. V.: Theoretical fundamentals of designing low-speed heavy-loaded spiroid gearboxes (2013).

## 5 Legacy and Today Interpretation of Contributions

The most important development of scientific achievements of Professor Veniamin Goldfarb is the creation of three independent scientific schools in Russia, two of them in Izhevsk and the third one in Novosibirsk. Three Doctors of Engineering Sciences in the field of MMS, machine parts and CAD systems continued their research with their own post-graduates that resulted (and are still functioning) in many other achievements, inventions and publications:

1. Professor Evgenii Trubachev (Izhevsk). In the essence, this school is a continuation and development of the scientific direction of Prof. V. I. Goldfarb Its specific features are:

    - orientation of computer-aided design methods towards real (different from ideal ones) conditions of gear operation—taking into account the production possibilities and errors, deformations, irreversible changes in tooth geometry (Goldfarb et al. 2003a, 2013c; Trubachev and Kuznetsov 2004; Trubachev et al. 2018a);
    - development of heavy-loaded varieties and expansion of traditional applications of worm-type gears, mainly with heat-strengthened steel gearwheels, including gears as an alternative to bevel and hypoid gears (Goldfarb et al. 2007a, 2009b, 2010, 2011a, 2019c; Goldfarb 2006a; Trubachev et al. 2018b; Trubachev 2021);
    - development of possibilities and minimization of the cost of gear production, including the development of new effective schemes and methods of teeth processing and contact localization (Goldfarb and Tkachev 2005a; Trubachev et al. 2018b, c; Trubachev and Puzanov 2012; Trubachev 2020a);
    - practical implementation of scientific developments in the design and serial production of gears and gearboxes at the small innovative enterprise "Mechanic" (Goldfarb et al. 2011a, 2015b; http://www.mipmechanic.ru.

2. Professor Valeriy Anferov (Novosibirsk) who created the direction "Spiroid gears in lifting and transport machines". The main scientific results are the developed calculation-experimental methods of estimation of friction coefficient, efficiency, wear and scuffing in spiroid gears—Fig. 8d (Goldfarb et al. 2011d, 2014a, c; Goldfarb and Anferov 1992, 1999, 2000, 2012).
3. Professor Olga Malina (Izhevsk) who began her scientific work in the field of formalization of the process of computer-aided design of gears and gearboxes and developed the ideas to general (invariant) approaches to classification, structural synthesis of complex objects and processes for various applications (Goldfarb et al. 2016a, 1994f, 1995b; Goldfarb and Malina 1999a, b).

Another important legacy is the creation and successful functioning of the gear production enterprise, which, in fact, emerged "out of nothing", relying almost entirely on the activity, energy and qualification of V. I. Goldfarb himself and his subordinated associates at the Institute of Mechanics. At first, the old machine-tools available at the department's training workshop were used (in many respects, restored and "revived"). During the first fifteen years (approximately by 2010) the company acquired its own machinery for the comprehensive support of the production process, its staff increased from 15…20 people to 70…80.

Applications for gears are as varied as they are traditional. Not only technical solutions, but also specific suppliers and manufacturers are often long-present. It is difficult for consumers to abandon them in favor of new ones. However, the situation in the 1990s, with the actual rejection of Soviet methods, bankruptcy of many enterprises, opening of the foreign market and foreign supplies of more advanced gear equipment on the one hand, and the galloping exchange rate of the foreign currency on the other, promoted the search for new solutions for both consumers and new manufacturers. Actuators for pipeline valves were a great finding for the team of Professor V. I. Goldfarb. Contrary to the general trend, production of the latter was constantly growing, first because of Russia's well-known specialization in the production and supply of hydrocarbons and then due to a rather rapid recovery of many other things in the production sphere. In the mid 1990s on the initiative of Cameronvolgomash enterprise (now Samaravolgomash) there was a meeting in Izhevsk with gear manufacturers with the issue of creating analogues to foreign products. The gear manufacturers said "definitely": "No. We do not have such design and production methods". And it was Professor V. I. Goldfarb invited to the meeting who uttered the famous Lenin's phrase in the USSR: "We have such a party!" The point here was not so much in V. I. Goldfarb determination and vigor, as in his deep understanding of gears—worm gears, used in analogs, and spiroid ones, which have a number of favorable properties for the successful application in conditions, typical for valve control—at low speeds, rare actuating and high overload torques. From that moment a multifaceted work on research, creation of methods and means for design, organization of pilot and then serial production of gearboxes for pipeline valves control began (Figs. 9 and 10).

The work started with experimental testing of future effective solutions. Several prototypes, differing in design, were broken during the tests. The result of the work (we dare to think, not final at all) was … let us quote our colleague and a long-time friend Prof. V. I. Goldfarb Dr. S. A. Lagutin: "A small innovative enterprise "Mechanic" cooperated with the Institute of Mechanics is producing now up to 1000 gearboxes per month (!), providing almost all pipeline valves in Russia with its production. As a manufacturer and supervisor of the gearbox workshop at Elekstrostal Heavy Engineering Plant, I can only be envious of such results". This is the most important practical result of Prof. V. I. Goldfarb initiative, which provided and continues to provide interesting work for dozens of specialists, for whom it became a great school. No less important scientific and manufacturing results that became possible due to it are as follows:

- theory of design of heavy-loaded spiroid and worm gears and gearboxes adapted to production and operating conditions (Goldfarb et al. 2011a; Goldfarb and Trubachev 2002b);
- invariant methods and software tools for synthesis of complex objects and processes (Goldfarb et al. 2016a);
- new types of gears (Goldfarb et al. 2009b; Trubachev 2021; Trubachev and Mogilnikov 2019);
- improved methods of gear cutting (Goldfarb et al. 2005c; Trubachev et al. 2018c; Trubachev 2020a, b).

To summarize, we must say: thanks to this, the scientific school of Professor V. I. Goldfarb became in many respects self-sufficient, well-motivated, capable of stating, discussing and solving important, useful and interesting problems in the field of gears and gearbox engineering.

Fig. 9 Small innovative enterprise "mechanic"—machining (**a**) and testing (**b**) sites

Life and science on gears do not stand still; many developments that were once pioneering turned to be trivial in the engineering practice now. Thus, the methods of algebra of logic and Boolean operations with three-dimensional objects became common in design, but we must remember that our teacher, Professor V. I. Goldfarb was the first to apply them and show their versatility by developing and implementing his non-differential method in the theory of gearing and the tooth generating theory.

Taking advantage of vast possibilities of modern computer applications for gear design, developing specialized programs for the calculation of their interesting versions, including non-standard ones, and looking for solutions in the great variety of spatial gear schemes, we must apply the general regularities discovered by him, thus accelerating the search, making it more meaningful both for the developer-researcher and for the user-engineer.

The tremendous impulse from Prof. Veniamin Goldfarb received by dozens of gear scientists, many of whom have headed scientific schools, and the charge of positive constructive communication between experts from different countries at scientific conferences and at national and international organizations and forums, thanks to

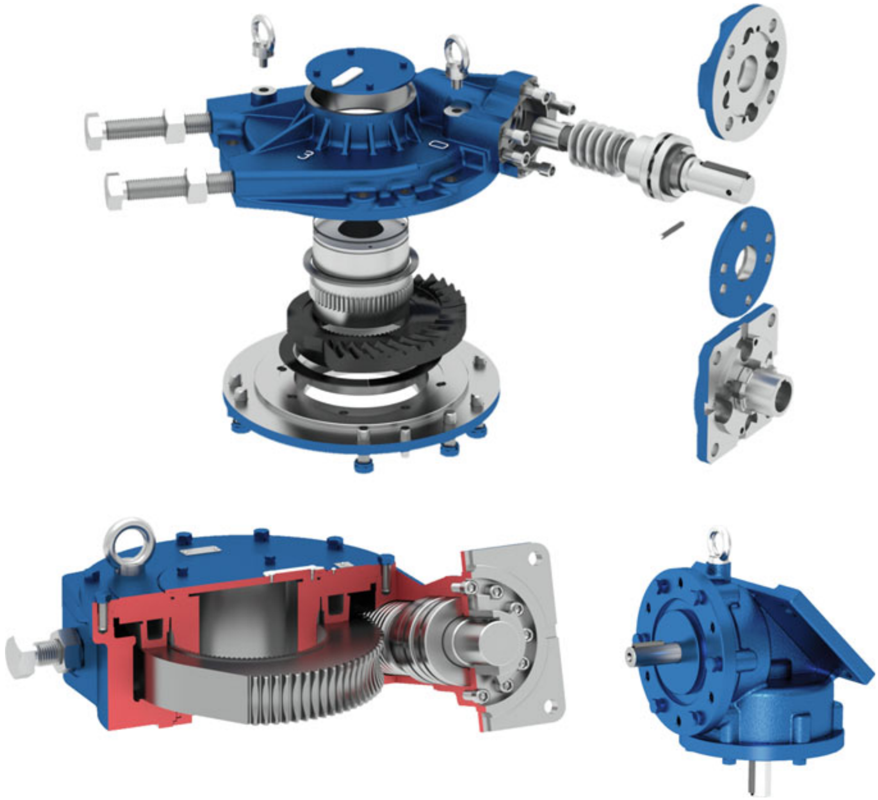

**Fig. 10** Gearboxes produced by SIE “Mechanic”

which the level of development is becoming more accessible to everybody, and the orbit of the theory of gearing and MMS studies as a whole is attracting new young personnel, is probably the most valuable gift of fate for many of those who knew Prof. Goldfarb and worked with him.

Finally, the small innovative enterprise "Mechanik", where tens of specialists made themselves not only as engineers, who proposed a lot of effective technical and industrial solutions, but also as researchers, who got the possibility to be involved in their favorite and interesting work (which is undoubtedly important for each of them), became the unique example of independent implementation of scientific developments, performed in the university environment into the real competitive business.

This is how we see the modern legacy of Professor V. I. Goldfarb. It has not faded into the past; it lives with us and many people who, perhaps, do not always think about this heritage when using it, perceiving it as a proper, self-evident, habitual part of their life and science.

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# Teru Hayashi (1932–2017)

**Nobuyuki Iwatsuki and Kazuhiro Yoshida**

**Abstract** Teru Hayashi was an outstanding figure in the world in engineering researches in gearing and micromechanisms/micromachines. He developed various methods to measure accuracy of large ship gears and proposed novel gear processing methods and gear tooth profile modification methods based on the accuracy measured with his methods. These results contributed to the dramatic improvement in machining accuracy of large gears in Japan. He also visualized the relations between gear tooth profile errors and gear vibration and noise generated by the tooth profile errors and revealed the suitable gear tooth profile modification to reduce gear vibration. He was one of the scholars to point out the future potential of micromechanisms/micormachines firstly in the world. He revealed scale effects on performance of mechanisms due to miniaturization and developed and prototyped various micromechanisms/micromachines based on novel drive principles. His works induced the global boom to develop micromechanisms/micromachines and lead to the establishment of Technical Committee of Micromechanisms, IFToMM. He was also the founder of Japanese Council of IFToMM as an official member organization of IFToMM. His dedicated efforts enabled Japanese researchers in mechanical engineering to participate in world IFToMM Community. Teru Hayashi was a truly great leader to promote the international cooperation among researchers on mechanism and machine science through his great research works.

N. Iwatsuki (✉)
Department of Mechanical Engineering, School of Engineering, Tokyo Institute of Technology, Tokyo, Japan
e-mail: iwatsuki.n.aa@m.titech.ac.jp

K. Yoshida
Laboratory for Future, Interdisciplinary Research of Science and Technology, Institute of Innovative Research, Tokyo Institute of Technology, Yokohama, Japan
e-mail: yoshida.k.ab@m.titech.ac.jp

 
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## 1 Biographical Notes

Teru Hayashi, Fig. 1, was born in Mobara, Chiba, Japan, on 26th August, 1932 and died in Yokohama, Kanagawa, Japan, on 7th September, 2017.

He graduated from Department of Mechanical Engineering, Tokyo Institute of Technology in March, 1956. His graduation research project was concerned with gear vibration and was conducted under the supervision of Professor Takashi Nakada (1908–2000) who was a very famous researcher in the world on profile-shifted gears and NC machine tools, and Associate Professor Jiro Ishikawa (1917–1998) who was an expert of gear accuracy measurement in Japan.

After the graduation, Teru Hayashi went to master course of graduate school, Tokyo Institute of Technology, however, he got a job as a research associate in Professor Nakada and Associate Professor Ishikawa's laboratory, Research Laboratory of Precision Machinery and Electronics, Tokyo Institute of Technology on 1st November, 1956 to accept Professor Nakada's strong request. Teru Hayashi mainly conducted researches on precision measurement of gears, then got degree of Doctor

**Fig. 1** Teru Hayashi (1932–2017) in 2012

of Engineering from Tokyo Institute of Technology on 24th November, 1965. The title of his doctor thesis was “Study on undulation of large gears”.

Teru Hayashi was promoted to an associate professor of the Research Laboratory of Precision Machinery and Electronics, Tokyo Institute of Technology on 1st March, 1967 and then promoted to a full professor of the same laboratory on 1st July, 1979.

During this period, for 11 months in 1974, he stayed at University of Massachusetts, United States of America and Technische Universität München, West Germany as a visiting scholar supported as Japanese Ministry of Education Overseas Researcher.

In March, 1993, Teru Hayashi retired from Tokyo Institute of Technology and became Professor Emeritus of Tokyo Institute of Technology. He promptly joined Faculty of Engineering, Toin University of Yokohama, Japan as a professor and served as the Dean, Faculty of Engineering for 5 years from 1998.

After the second retirement from Toin University of Yokohama in March, 1998, he served as a technical advisor of Ogasawara Precision Laboratory Co. Ltd. and Nishijima Corporation and was an active researcher up to his dying day.

Teru Hayashi served key positions in the following various academic societies and associations in Japan and in the world and contributed to the promotion of mechanism and machine science:

Domestic:

- July, 1978–March, 1981: Vice chairman, Executive committee, Japanese Council of IFToMM
- May, 1980–April, 1986: Board member and auditor, The Japan Society for Precision Engineering
- July, 1983–June, 1986: Chairman, RC-69 research subcommittee on gearing, The Japan Society for Mechanical Engineers
- April, 1986–March, 1989: Chairman, spline standard committee, Society of Automotive Engineers of Japan
- May, 1986–April, 2015: Chairman, Planning committee, Japan Gear Manufacturers Association
- April, 1989–March, 1992: Chairman, ISO/TC14 investigation committee, The Japan Society for Mechanical Engineers
- April, 1989–March, 1992: Chairman, Executive committee, Japanese Council of IFToMM
- April, 1990–March, 1992: Chairman, Investigation committee on realization of micromechanisms with precision engineering
- September, 1990–August, 2002: Chairman, Cooperative research committee on manufacturing of micromechanisms, The Japan Society for Precision Engineering
- July, 1991–June, 1993: Chairman, Executive committee of Motion Engineering Exhibition, Techno Frontier Exhibition, Japan Management Association

International:

- January, 1984–December, 1991: Executive council member, IFToMM

- August, 1991–July, 1995: Chairman, Technical Committee of Micromechanisms, IFToMM
- 1993, General Chairman, The 1st IFToMM International Micromechanism Symposium
- September, 2007–September, 2017: Honorary member, IFToMM

## 2 Researches on Gearing

Teru Hayashi started his academic career in November, 1956 as a research associate of Research Laboratory of Precision Machinery and Electronics, Tokyo Institute of Technology, Japan. He belonged to Professor Takashi Nakada and Associate Professor Jiro Ishikawa's laboratory. Teru Hayashi had hoped to research automatic control systems, however, Prof. Nakada strongly recommended him to research gearing because Prof. Nakada had highly evaluated his abilities.

Under the supervision of Associate Professor Ishikawa, Teru Hayashi started conducting various experiments to measure gear accuracy with various measurement devices using a condenser micrometer. The measured results and various calculations and charts proposed by Teru Hayashi were utilized to make drafts of Japanese Industrial Standards (JIS) on measurement of gear accuracy. In those days, the calculations were conducted with a hand-cranked mechanical calculating machine, an involute function table and Teru Hayashi's enthusiasm. Especially, he proposed a curve chart to effectively measure and calculate tooth thickness of helical gears. This curve chart is still in use today in industries. Since that time, Teru Hayashi had concerned to establish JIS on gear accuracy and its measurement for fifty years.

The shipbuilding boom which arrived in Japan in 1958 requested Japanese industries to improve performances of large marine turbine gears which had been manufactured mainly in foreign countries. Then, a large-scale industry-government-academia research project, "Research Group to Improve Marine Gear Technology" was established with Prof. Nakada as a chairman. Teru Hayashi belonged to its subgroup on gear accuracy and was entrusted to design and prototype gear accuracy measuring devices to measure large gears with 5 m in diameter and 35 t in weight. Because such large gears could not be set on a specimen fixing axis of dedicated measuring machines, it was required to develop a new on-hand measuring device with an easy calculation method. Figure 2 shows a photograph of Teru Hayashi measuring tooth profile error of a large gear with tooth profile measuring device proposed by him.

Teru Hayashi visited many factories of marine gear manufacturers in Japan and measured various gear accuracies with gear accuracy measuring devices developed by him. Those measured and analyzed results were utilized to improve the tooth modification of master gears of gear hobbing machines and gear shaving method then resultantly, accuracy of Japanese large marine gears became the best in the world.

The most important achievement in Teru Hayashi's research on gear accuracy was to develop measuring devices and calculation method to measure undulation

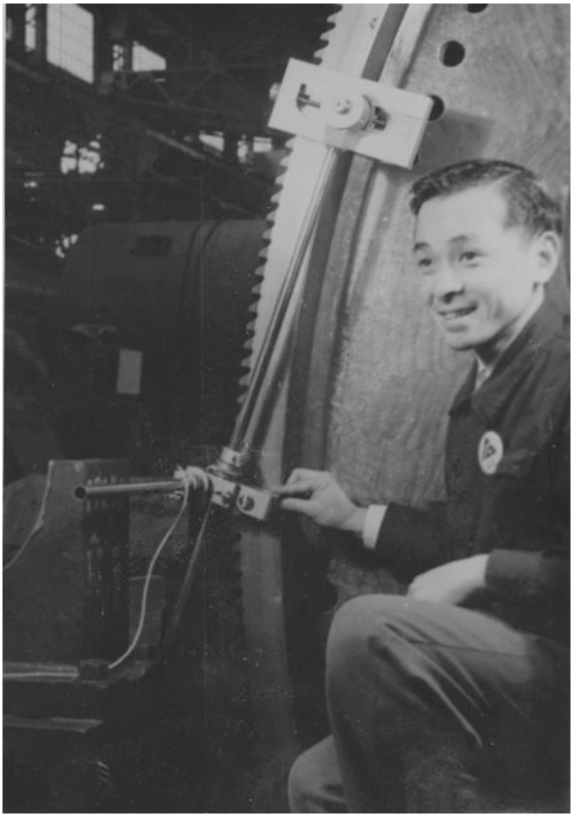


**Fig. 2** Measurement of pitch error of a large marine gear in 1961

error of large marine gears. He proposed many measuring devices and method to calculate undulation error component from the measured data and finally developed a built-in measuring and analyzing system for gear tooth undulation (Hayashi 1965a, b, c). Figure 3 shows photographs of gear undulation measuring devices developed by him.

Teru Hayashi summarized these results and submitted his doctoral dissertation entitled as "Study on undulation of large gears (Hayashi 1965d)", and then he was awarded the degree of Doctor of Engineering by Tokyo Institute of Technology in November, 1965. On 1st March, 1967, Teru Hayashi was then promoted to an associate professor because his research works ware highly evaluated.

Teru Hayashi continued researches on gearing in Tokyo Institute of Technology. He focused on dynamic load balancing in planetary gear drives and revealed that spring characteristics of lubricant film on planetary gear shafts made dynamic load balanced. A new planetary gear drive invented based on this principle was called as "IMT planetary gear drive" and obtained a patent which won the Product Award from the Japan Society for Mechanical Engineers in 1969. Figure 4 shows a main part of mechanism of the IMT planetary gear drive.

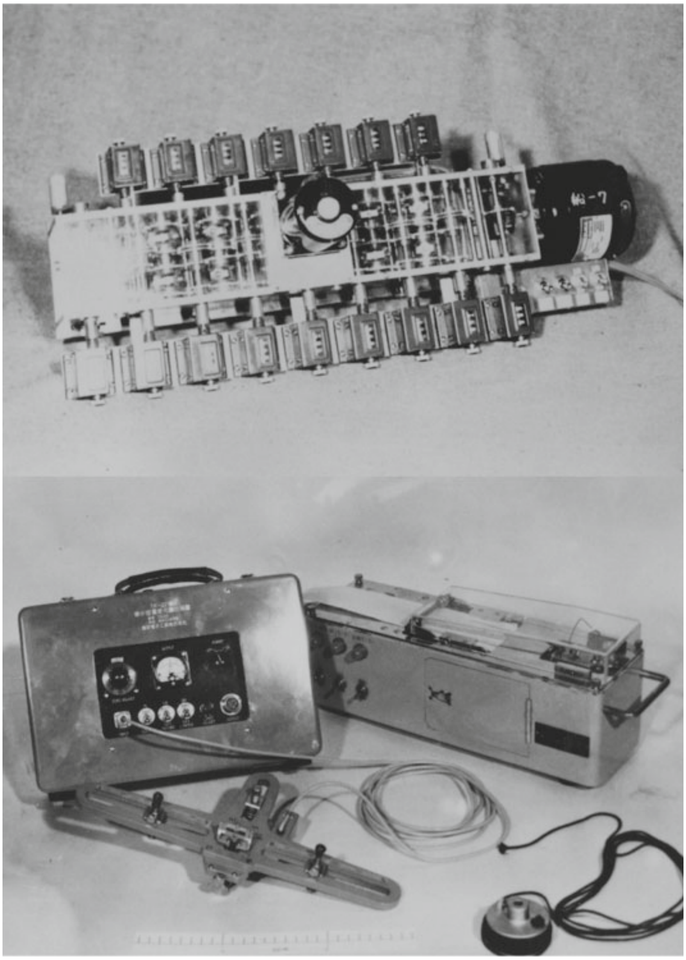


**Fig. 3** Undulation measuring devices developed by Teru Hayashi

Teru Hayashi also succeeded to expand this principle to apply to general planetary gear drives and to establish 'Theory of dynamic balance in planetary gear drives (Hayashi et al. 1970)'. He also investigated the transmission of dynamic load and torque in the complicated planetary gear drives such as a multi-stage planetary gear drive and proposed "the torque flow chart method" as a simple graphical method which even beginners could easily understand.

Teru Hayashi applied the mechanical–electrical analogy, which Prof. Nakada had often used to solve various engineering problems, to dynamic meshing tester to precisely measure dynamic torque variation due to gear tooth profile error. An equivalent electronic circuit corresponding to mechanical part of the tester was designed and prototyped. The transmitted torques in the input and output shafts were measured

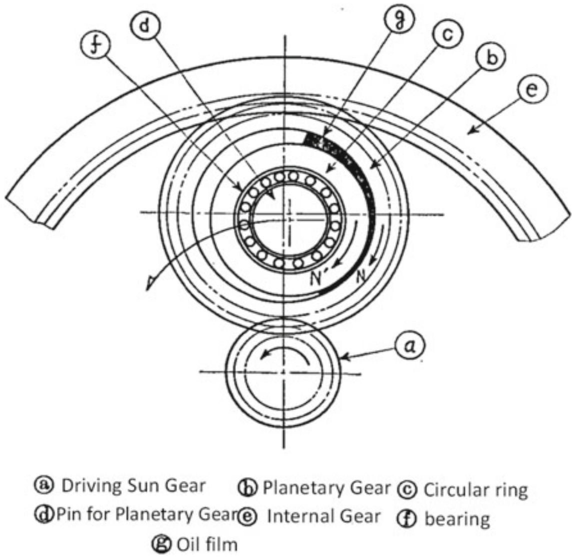



**Fig. 4** Main part of IMT planetary gear drive invented by Teru Hayashi

with dynamic strain meters and were inputted to the electronic circuit as voltage signals. Resultantly, the electric current corresponding to dynamic gear transmission error could be measured. Because operational amplifiers to represent nonlinear stiffness of gear tooth were installed in the electronic circuit, the dynamic gear transmission error could be measured and evaluated with an adequate accuracy. Figure 5 shows the developed dynamic meshing tester (Hayashi and Hayashi 1973).

Because these excellent research works were highly evaluated, Teru Hayashi was promoted to a full professor of the Research Laboratory of Precision Machinery and Electronics, Tokyo Institute of Technology on 1st July, 1979. In order to meet the requirements of industries having many problems on gear vibration and noise, Teru Hayashi was elected as a leader of a large-scale industry-academia research project to investigate the relation between gear tooth profile error and vibration and noise characteristics of gear drives. In the project, he prototyped many specimen of spur gears with various tooth profile errors including various tooth profile modifications and precisely measured tooth profile errors and vibration and noise generated by the pair of the tested gears in order to find the relation between gear tooth profile error and gear vibration and noise. Teru Hayashi then proposed a new idea to represent features of tooth profile error. Amplitudes and phases of frequency components of a tooth profile error were calculated with Fourier transform and the polar coordinate vectors represented with the calculated amplitude and phases were serially connected in order. Teru Hayashi named this chart as "tooth profile error vector chart" and classified types of tooth profile error based on the shape of the tooth profile error vector chart (Hayashi and Hayashi 1977). Figure 6 shows several examples of tooth profile error vector charts. The feature of a tooth profile error can be visualized with the bending shape of connected vectors as frequency becomes higher. He explained

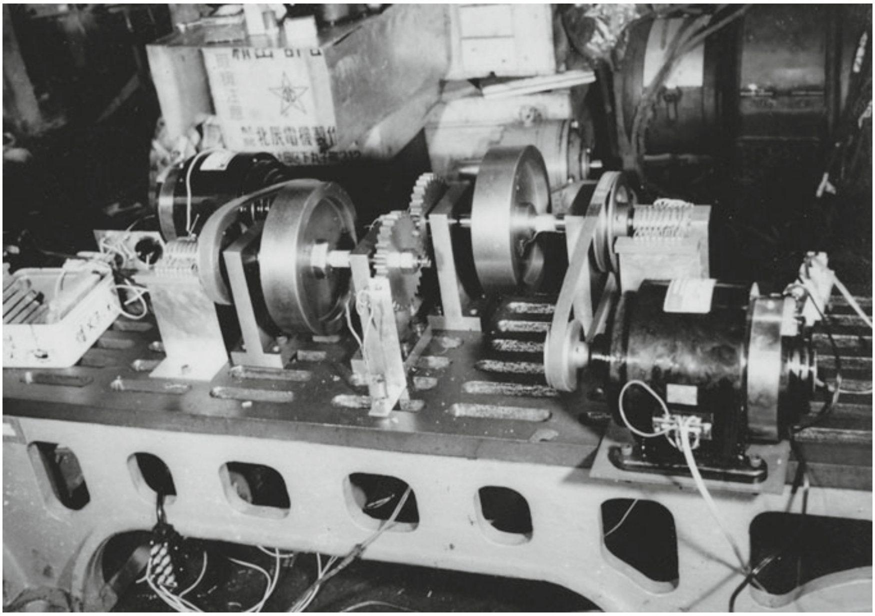


**Fig. 5** The developed dynamic gear meshing tester

the relation between gear vibration and noise measured with experiments and the feature of tooth profile error and then theoretically estimated the vibration response of spur gears due to gear tooth profile error based on the approximated vibration analysis (Cai and Hayashi 1990). Furthermore, the ideal tooth profile modification to make vibration zero was theoretically calculated (Cai and Hayashi 1991).

In order to eliminate backlash of gears, Teru Hayashi tried to develop no-backlash gear drives. In his prototype, gears on an intermediate gear shaft were simultaneously pressed to driving and driven gears in the direction perpendicular to gear shafts, therefore, all gears usually kept both tooth surface meshing.

A special bearing unit composed of many steel plates and thin rubber layers was proposed and prototyped by Teru Hayashi so as to give precision small displacement to the intermediate gear shaft.

## 3 Researches on Micromechanisms

While promoting researches on gearing, Teru Hayashi perceived that the demand for large gears would decrease, because depression on shipbuilding occurred around 1970, and main engines of large ships had been changed from steam turbines to diesel engines. Then, he investigated sizes and added value (price for 1 g) of gears and found that the added value of precision master gears is far higher than that of large gears for

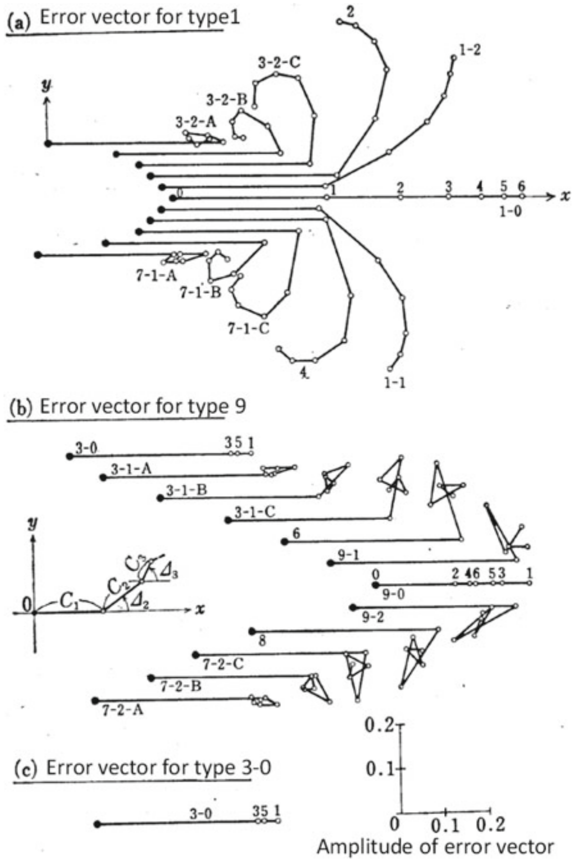
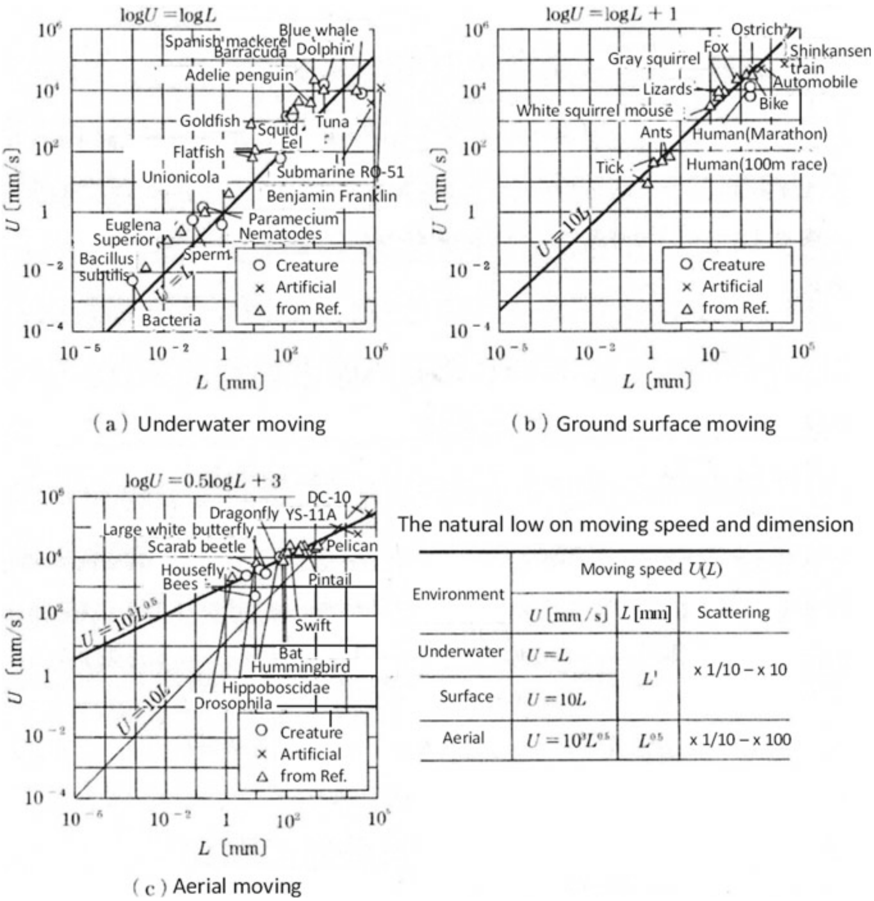



**Fig. 6** Error vector chart for gear profile error

ships with 5 m in diameter and 35 t in weight. Furthermore, extending the research subjects to general mechanical elements, he found that their added value increases logarithmically with decreasing their sizes. Hence, he decided his new research subject to be creating small and minute machines and named them "micromechanisms". Then, statistically evaluating the relation between moving speed and length of not only moving machines but also moving living things, he clarified their miniaturization characteristics (scale effect) as shown in Fig. 7. In addition, he clarified the scale effects of drive performance of machines, measurement characteristics, processing characteristics, control characteristics and so on and obtained the theoretical background to realize the micromechanisms (Hayashi 1986, 1988; Hayashi and Yoshida 1991).

Teru Hayashi performed not only theoretical investigation but also proposal and fabrication of the micromechanisms based on novel driving principles. The first prototype was an in-pipe traveling micromechanism shown in Fig. 8. It was composed of three pneumatic inflatable balloons, each of which extended in a specific direction




| Environment | Moving speed $U(L)$ | | |
|---|---|---|---|
| | $U$ [mm/s] | $L$ [mm] | Scattering |
| Underwater | $U = L$ | $L^1$ | x 1/10 – x 10 |
| Surface | $U = 10L$ | | |
| Aerial | $U = 10^3 L^{0.5}$ | $L^{0.5}$ | x 1/10 – x 100 |

**Fig. 7** The relation between moving speed and length

with reinforced fibers. Its diameter was only 10 mm and it could travel with pressure control of one pneumatic circuit (Hayashi and Yoshida 1991).

Among many proposed micromechanisms, a surface traveling micromechanism fabricated in 1981 was a masterpiece. It was an arched piezoelectric film bimorph of arrow-shaped as shown in Fig. 9. The micromechanism vibrated with applied AC voltage could travel back/forward and right/left quickly by changing the frequency of applied voltage. He named this micromechanism as the micro-cockroach. This very simple micro-cockroach could produce sufficient mechanical power. The research pioneered the novel technological field before development of micro gear trains (Mehregany et al. 1988) and micro electrostatic motors (Fan et al. 1989) which were fabricated on silicon wafers using semiconductor etching technologies after 1988.

By making the best use of the characteristics of micromechanisms, Teru Hayashi proposed a ceiling traveling micromechanism (Shibagaki et al. 1992) shown in

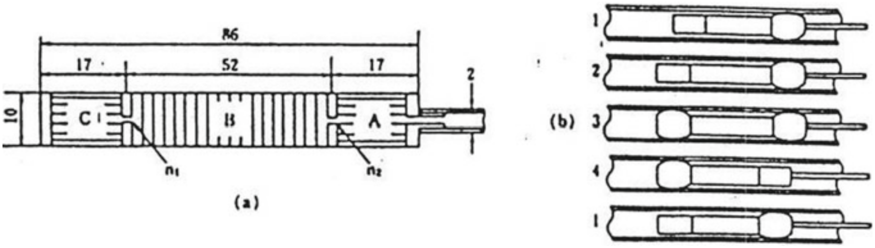



**Fig. 8** In-pipe traveling micromechanism composed of three air balloons

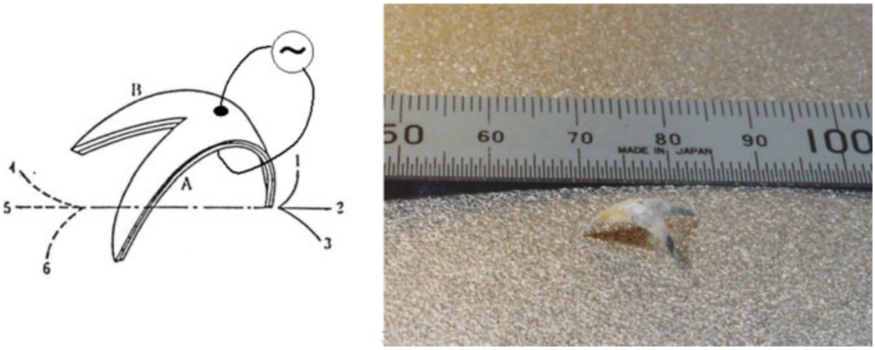



**Fig. 9** Surface traveling micromechanism composed of piezoelectric film bimorph

Fig. 10. Using the adsorption force due to surface tension of water which is especially effective in small size, the micromechanism could travel on ceilings against the gravity.

Furthermore, he focused on the high water absorbent electrolytic polymer-gel. The gel absorbs water and swells up to 3000 times of its original volume, and discharges and shrinks when electric field is applied to it. By utilizing the large reversible volume change, he developed the micromechanisms and microactuators (Terashima et al. 1991; Hayashi et al. 1993).

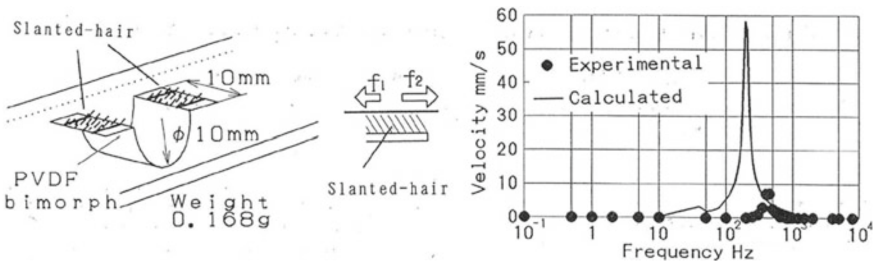



**Fig. 10** Ceiling traveling micromechanism and its velocity

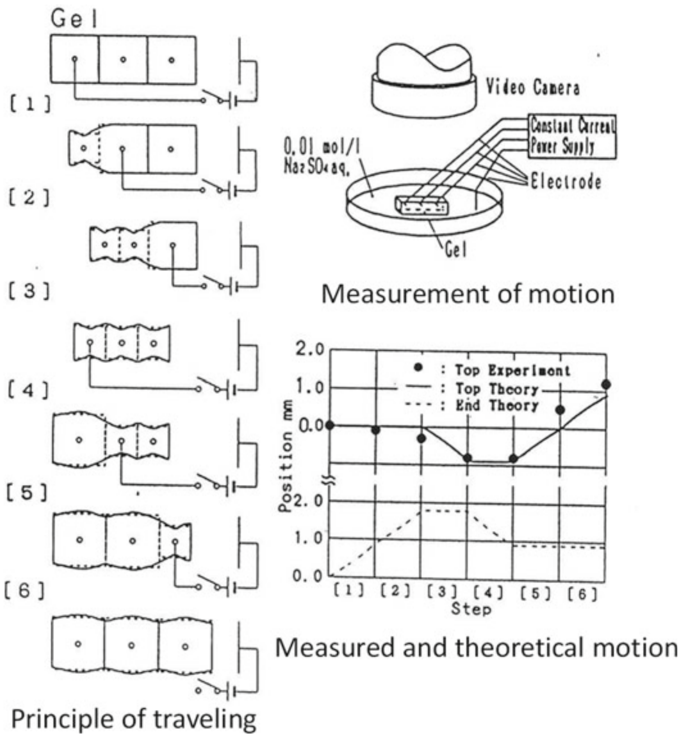



**Fig. 11** Micro caterpillar made of high water absorbent electrolytic polymer-gel

Figure 11 shows a micro caterpillar made of high water absorbent electrolytic polymer-gel. Figure 12 shows a gel motor which was rotated by pushing its eccentric rotor with successively swelled four spheres of high water absorbent electrolytic polymer-gels.

Collecting kindred minds, Teru Hayashi first organized “Research Group of Micromechanisms” in Tokyo Institute of Technology. Then, he organized “Technical Committee on Micromechanisms” in the Japan Society for Precision Engineering (JSPE). In the annual conferences of the JSPE, contests of fabricated micromechanisms called “International Contests of Micromechanisms” were held, which expanded the range of research field of the micromechanisms. Figure 13 shows a photograph of the first contest “Contests of Mountain Climbing Micromechanisms”. The micromechanisms were within a cubic of 1 cm$^3$ and the target mountain was a pressed steel plate of 10 cm height. In the contest, the running times of micromechanisms for the requested path was compared to each other. He designed the rules and the stadium of mountain.

The researchers on micromechanisms has been spread around the world. In the IFToMM, “Technical Committee for Micromechanisms” was set up under the chairmanship of Teru Hayashi.

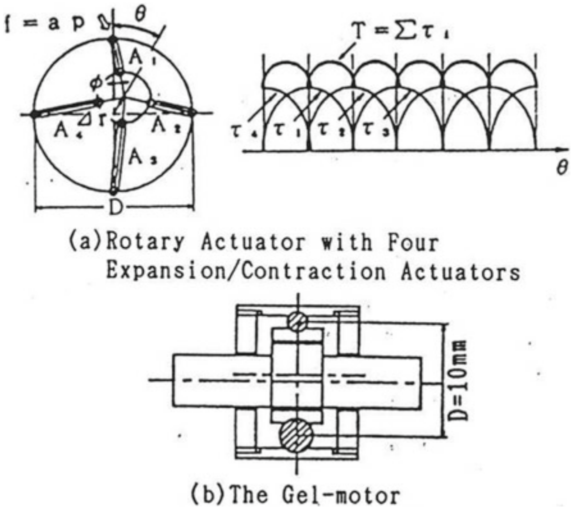



**Fig. 12** Gel motor

**Fig. 13** The 1st Contest of Mountain Climbing Micromechansims in JSPE spring conference in 1990

As mentioned above, we would like to keep in mind that Teru Hayashi was a great meritorious person who promoted initial development of the present micro/nano technologies.

## 4 Researches on Various Precision Measurement

Since Teru Hayashi researched on measurements of undulation of large gears for ships, the precision measurements had been his field of expertise. On the basis of outstanding ideas, he developed many kinds of precision measurement devices.

To precisely measure the noise of gearing with high directivity, according to JIS, 24 microphones are required to locate around the measuring object, which is very complicated procedure. He proposed a real-time measurement method of radiated sound pressure distribution of a target object using a two-dimensional microphone array located near a focal point of a parabolic sound collector and realized a real-time sound pressure distribution visualizing device. The device had an LED array in which optical intensity of each LED was in proportion to the sound pressure measured with a microphone in the microphone array and overlapped the image of the LED array onto the real scenery image using a half mirror. Figure 14 shows a photograph of a sound source exploration device developed in a collaborative research with a company. By using the device, noise sources of construction machinery could be explored in real time.

When Teru Hayashi investigated accuracy of gears, there was a need to measure rotational velocity variation of a table of a gear hobbing machine, which gave a fatal effect on the accuracy of gears. The rotation velocity was very low and was influenced by the earth rotation, hence it was very difficult to measure the velocity variation. To overcome the problem, he proposed a novel measurement method on the basis of precession of a gyro. Through trial and error, supporting the axis of gyro by an ultra-precision air bearings and using servo control, he succeeded to realize the precise measurement of velocity variation of $10^{-7}$ order. As mentioned above, Teru Hayashi was an outstanding researcher who can realize precise measurements by combining many kinds of measurement technologies.

## 5 Researches After Retirement

After retirement from both Tokyo Institute of Technology and Toin University of Yokohama, Teru Hayashi was an active researcher/educator as a technical advisor at two companies. One of the companies, Ogasawara Precision Laboratory Co. Ltd. is a leading company manufacturing ultra-precision gear hobbing machines, master gears, and several kinds of testing machines. Teru Hayashi started researching on accuracy improvement of the products. Especially, he achieved higher precision of gear measuring equipment and higher precision machining of microgears. He

**Fig. 14** The developed sound source exploration device with a parabolic sound collector and a microphone array

received the JSPE Numata Memorial Paper Award in 2007 for "Study on the Basic Axis Formation of Ultra Precise Gear Measuring Instrument". Figure 15 shows the fabricated microgears (Ogasawara et al. 2007). He seemed to take delight in achieving significant results by recurring to the researches on gearing.

## 6 Contribution to IFToMM

Teru Hayashi stayed at Professor Erskine Crossley's lab, University of Massachusetts, United States of America as a Japanese Ministry of Education Overseas Researcher for 11 months in 1974. Prof. Crossley was the 1st Editor in Chief of Journal of Mechanisms and was also a vice president of IFToMM which was established in September 1969.

During Teru Hayashi's stay, Prof. Crossley often explained him that the important missions of IFToMM were to promote international exchange of researchers on mechanism and machine science and to support developing countries and that Japanese researchers in the field were strongly expected to join activities of IFToMM. This was the beginning of his long-term relationship with IFToMM. Figure 16 shows a photograph of reunion of Teru Hayashi and Prof. Crossley in 1997.

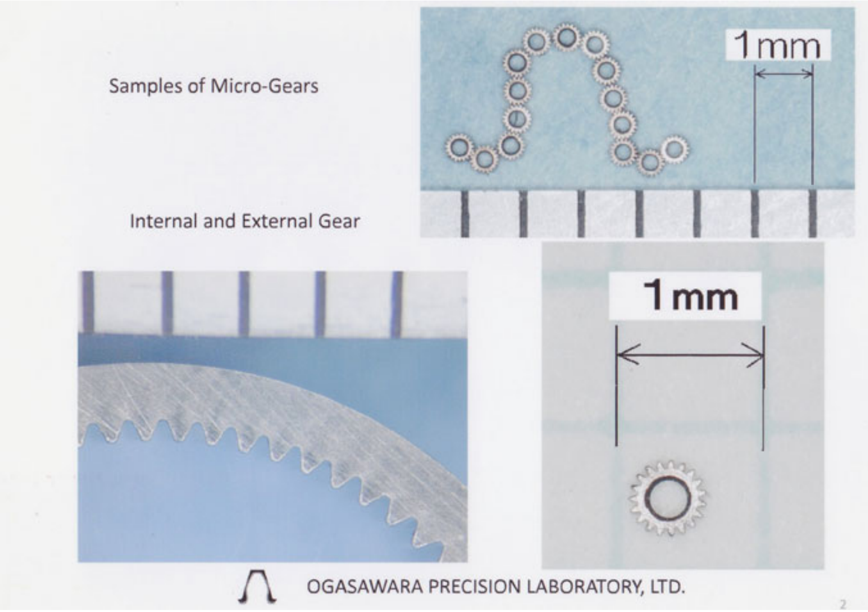



**Fig. 15** Ultra precise machining of microgears

**Fig. 16** Photograph with Prof. Erskine Crossley in 1997

Teru Hayashi immediately understood the importance of IFToMM activities through Prof. Crossley's talk. After Teru Hayashi returned to Japan, he started recruiting comrades in Japanese researchers on mechanism and machine science and petitioned the Japanese Government (Ministry of Education), Science Council of Japan, and many academic societies and research institutions in industries which were related to mechanical engineering in order to establish Japanese organization related to IFToMM.

Teru Hayashi's effort made his wish come true. In July, 1978, Japanese Council of IFToMM (Jc-IFToMM) was established in the Japan Society of Precision Engineering. He succeeded to gather 174 individual members and 4 supporting members and became the founder of this Jc-IFToMM which has continued to date. Teru Hayashi invited Prof. Jiro Ishikawa as the chairman and supported him as the vice chairman.

Under Teru Hayshi's active effort, Jc-IFToMM could join IFToMM as one of member organizations. Jc-IFToMM has continued to hold an annual meeting, a symposium and special lectures/seminars/visits every year and to publish a bulletin, Jc-IFToMM News. Recently, Jc-IFToMM secures the status of influential members in the world IFToMM through the cooperation to many TC's activities and IFToMM World Congress.

Teru Hayashi was elected one of the Executive Council members of world IFToMM during 1984–1987 and strived for management of world IFToMM community. In September, 1992, Teru Hayashi established the Technical Committee for Micromechanisms in the world IFToMM and became the first chairman of the Technical Committee.

During 1989–1993, Teru Hayshi managed Jc-IFToMM as the chairman and promoted the collaborations with world IFToMM community. Especially, the IFToMM-Jc International Symposium on Theory of Machines and Mechanisms (International Festival on Mechanism'92) was held in September, 1992 in Nagoya and the 1st IFToMM International Micromechanism Symposium was held in June, 1993 in Tokyo. Teru Hayashi demonstrated his leadership and hospitality to make the both symposia success. Figures 17 and 18 show photographs of the IToMM-Jc International Symposium on Theory of Machines and Mechanisms—International Festival on Mechanism'92 and the 3rd IFToMM International Micromechanism Symposium held in September, 2001, respectively.

Teru Hayashi was recognized for his many years of achievements and contributions in IFToMM community and was then elected as an Honorary Member of IFToMM in the General Assembly in the 12th IFToMM World Congress which was held in Besançon, France in June, 2007. Figures 19 and 20 show photographs in the awarding ceremony in that time.

Based on Teru Hayashi's many years of efforts and contributions mentioned above, Jc-IFToMM could hold a new international conference, IFToMM Asian Conference on Mechanism and Machine Science in 2012 in Tokyo and succeeded to invite the 16th IFToMM World Congress. This congress as Jc-IFToMM's long-cherished wish will be held in November, 2023 in Tokyo.


**Fig. 17** Photograph at IToMM-Jc International Symposium on Theory of Machines and Mechanisms—International Festival on Mechanism'92

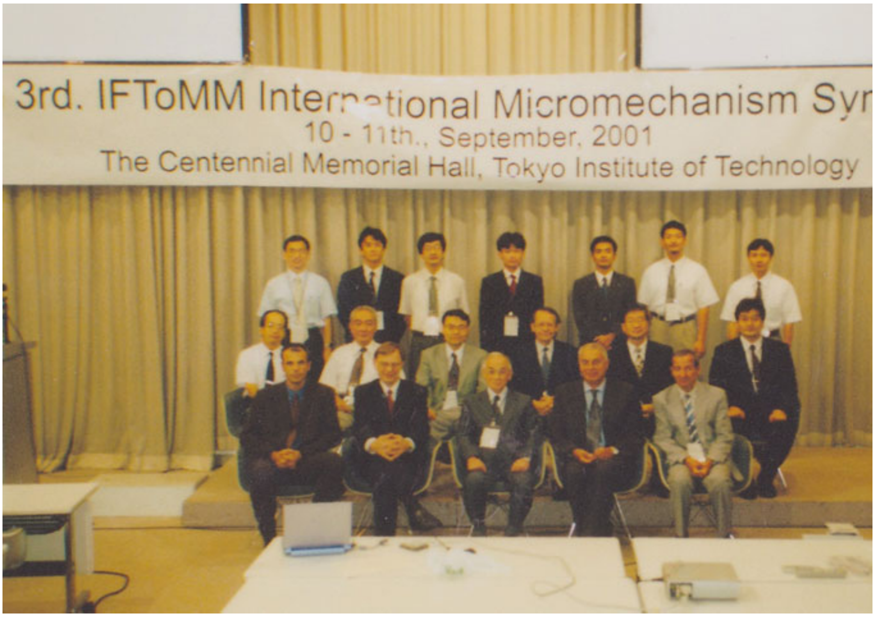



**Fig. 18** Photograph at 3rd IFToMM International Micromechanism Symposium in Tokyo in 2001

**Fig. 19** Photograph at IFToMM Awarding Ceremony in IFToMM World Congress 2007

**Fig. 20** Photograph at IFToMM Awarding Ceremony with IFToMM EC members

## 7 Hobbies

When Teru Hayashi was a research associate at the Research Laboratory of Precision Machinery and Electronics, Tokyo Institute of Technology, his laboratory became a playground after his colleagues went home in the evening. He enjoyed fabrication of audio amplifiers and newly developed tape recorders, sometimes did it all night.

In those days, also being a tutor for the son of Prof. Takashi Nakada, Teru Hayashi lived in Prof. Nakada's home and could catch a glimpse of activities of the great senior master at home. The half of a large table at Prof. Nakada's home was occupied with literatures, materials, stationery, calculator, and calculating sheets, however, on the other half, there were assembling plastic models of airplanes and their tools. Prof. Nakada moved continuously his chair from side to side, alternated work and play, and sometimes enjoyed playing the flute for refreshing until late at night. Teru Hayashi watched Prof. Nakada's activities and experienced "Play-Work Unified Life" which Prof. Nakada advocated, and finally he followed that way of life. In addition, he attended garden parties which were held at Prof. Nakada's home with invited excellent foreign researchers, made many foreign friends, and made up his mind of international exchange and cooperation.

To act up to the mentor Prof. Nakada's "Play-Work Unified Life", he had many hobbies. The one was playing music instruments. Like Prof. Nakada, he enjoyed playing the flute, gave concerts and played in recitals even in his later years, by which he freshened his thinking after the research work. He did not play the flute in his own way, but he learned it from specialized musicians. Figure 21 shows a photograph of his flute recital at the age of 80. In addition, many of overseas travel souvenirs were local antique music instruments and he did not only display but also tried to play them.

The other enjoyment was travel. In international conferences, Teru Hayashi participated in excursions with his wife, Mrs. Yasuko Hayashi happily. Especially after retirement, Mr. and Mrs. Hayashi enjoyed traveling, so as to travel all over the world. Figure 22 shows a photograph of them at Machu Picchu, Peru in 2011. For those grand tours, not only endless curiosity but also physical strength is needed. Teru Hayashi was a really active person.

## 8 Conclusion

Teru Hayashi started the research and education on gearing, especially on precision measurements and evaluation of large marine gears, and begun the research and education on the micromechanisms for the first time in the world. The research field on the micromechanisms was novel and even fabrication was challenging, however, he showed many kinds of actual micromechanisms and micromachines and theoretical relation between sizes and mechanics of machines, by which he would be able to produce the present active field of micro/nano machines.

**Fig. 21** Photograph at the flute recital in 2000

**Fig. 22** Photograph with Mrs. Yasuko Hayashi at Machu Picchu in Peru

The ideas might be obtained by comprehensively observing the future of mechanical engineering in good time in "Play-Work Unified Life" affected by his mentor Prof. Nakada. Also with his magnetic personality, many researchers gathered and active organizations were established (Hayashi 2006), which includes Japanese Council of IFToMM, academic-industrial collaboration research projects on gearing, research group of micromechanisms in Japan, Technical Committee for Micromechanisms in the world IFToMM, etc. The members belonging to those societies would like to feel deep appreciating for Teru Hayashi.

Furthermore, he was an active researcher for a long time. After retirement from two universities, he presented his own research results as a technical advisor at two companies. It is interesting that recurring to the researches on gearing, through developments of high precision gears and microgears, he emphasized gears which are significant elements for humans. He explained importance to continuously learn one research field and thanked the learned matters for helping him.

We expect that the next generation researchers/educators who inherit the developed field from Teru Hayashi will develop the field more, referring his way of research, education, and engineering community developments. Especially, the researches on gearing are sometimes regarded as conventional and humble in the developed countries including Japan and they do not seem to be so active. We would like to note the importance to continuously learn one field and to make use of them as Teru Hayashi showed.

**Acknowledgements** Sorting through Teru Hayashi's personal effects, his posthumous manuscripts of autobiography was found in his personal computer. As that was almost completed, with the effort of his wife, the late Mrs. Yasuko Hayashi and his nephew, Mr. Kenzo Asakura, it was published with the title of "Get in touch with people with peaceful face and gentle words—Teru Hayashi's autobiography" (Hayashi 2018). This manuscript frequently referred to the book. We would like to express our deepest gratitude here.

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# Carlos López-Cajún (1948–2020)

**Marco Ceccarelli and Juan Carlos Jauregui Correa**

**Abstract** Prof. Carlos López-Cajún has been a prestigious figure, who has been admired worldwide also for his unique attitude to combine friendships and scientific activity in working the true spirit of IFToMM for collaboration, sharing, and improving the technology for the benefit of the society in the welfare of human beings. Prof. Carlos López-Cajún has been a great IFToMMist contributing and significantly supporting activities of the Permanent Commission of History of MMS in organization of events and exploration of the history of IFToMM and MMS with very valuable publications. Prof. López-Cajún devoted his acquired knowledge and expertise to the mechanical design, mainly on kinematic optimization of mechanisms, robotics and synchronization of mechanical systems publishing valuable results in papers in recognized journals, books and proceedings of international congresses. He served IFToMM as Member of the PC on History of MMS, member of the Executive Council and also as Secretary General. Moreover, he participated in the organization of the 13th IFToMM World Congress in 2011, and many among many other initiatives he also organized the HMM2016 Symposium in his city Queretaro in 2016.

## 1 Biographical Notes

Carlos Santiago López-Cajún, Fig. 1, (he used in general only the given name Carlos) was born on January 18, 1948, in Campeche, Mexico and passed away on Sunday 20

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M. Ceccarelli (✉)
Tor Vergata Rome University, 10133 Rome, Italy
e-mail: marco.ceccarelli@uniroma2.it

J. C. J. Correa
Autonomous University of Querétaro, Querétaro, México
e-mail: jc.jauregui@uaq.mx

 
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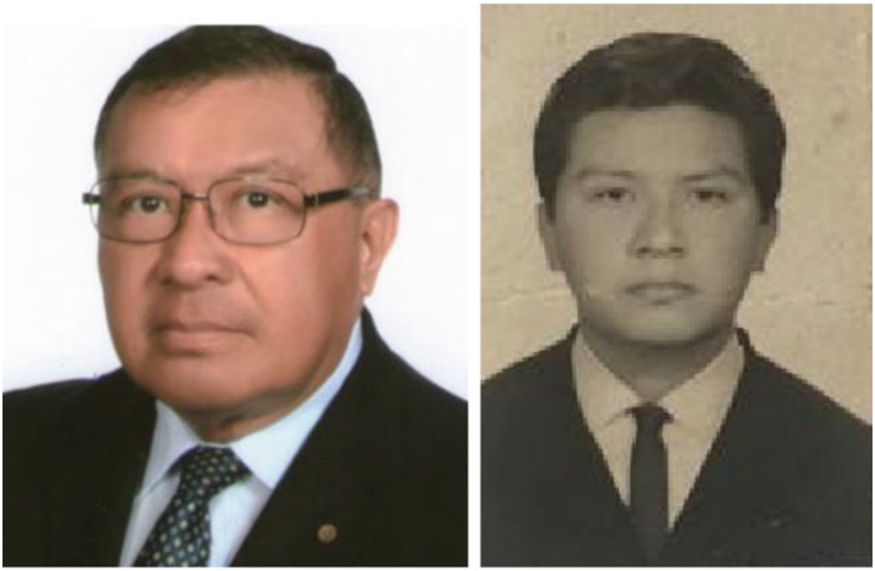


a) b)

**Fig. 1** Prof. Carlos S. López-Cajún (1948–2020): **a** in his maturity as professor at University of Queretaro; **b** when student at UNAM in Mexico City

December 2020 in hospital in Queretaro, Mexico (López-Cajún 2018, 2022; Acevedo and Ceccarelli 2022).

Prof. López-Cajún spent his childhood in Campeche where the family is still based, Fig. 2. There he formed his warm character with a calm behavior as always available to interact and help people, while staring to have interest in technology and particularly to machinery.

Prof. López-Cajún got his Bachelor and Master degrees on Mechanical Engineering in 1969 and 1977 from Universidad Nacional Autónoma de México (UNAM) in Mexico City, Fig. 1b, and his Ph.D. from Case Western Reserve University, USA in 1982. After the bachelor's degree he worked from 1969 to 1972 at the companies Panamerican Valves and from 1972 to 1975 at the Mexica Bus Company in Mexico City getting a strong experience of industry frames and relationships. During the period of strong dedication to studies and formation at the Department of Mechanical Engineering of UNAM in Mexico City he had the chance to meet and collaborate with Professor Ricardo and Enrique Chicurel who were later his mentors and supporters in promoting internationalization of the Mexican community, not only with links to IFToMM. In this period, he also started a long-life friendship with Jorge Angeles, who was at that time senior student in UNAM attending the same department of the professors Chicurel, and later with him he had strong long scientific collaboration mainly in the topics of mechanism and particularly cam transmissions, while Jorge Angeles became professor at McGill University in Montreal, Canada. The experience in USA for his Ph.D. degree was also formative in having not only been formed

**Fig. 2** Prof. López-Cajún with his grandmother in Campeche, Mexico

in other fields than mechanisms, but also to have experiences in USA with a first international vision.

After returning from USA to Mexico with the Ph.D. degree, Prof. López-Cajún worked from 1988 to 1995 in Industry at Mexican Institute of Transportation in Queretaro acquiring a professional experience, also as leader positions, that gave him also a better practical view of the need of academic formation with practical engineering aspects. During this period, he also had the chance to know the professional and industry communities with whom he maintained the contacts for long time. This experience was also useful to have a clear motivation to return to the academic frames.

While employed in Industry he was also part-time Professor at the Faculty of Engineering of UNAM in Mexico City. Then upon invitation by Jorge Angeles he spent sabbatical leaves in 1986–87 as Visiting Researcher at McGill University, Quebec, CA, and at University of Notre Dame, USA.

Then in 1996 he moved to Universidad Autónoma de Querétaro, campus San Juan del Río, where he got the position of Full Professor in Mechanical Engineering in same year starting there regular and continuous activity in teaching and research. He remained very active there until his last days, with increase of activity not only on local and national frames but also at international levels and mainly in IFToMM community.

Since the beginning of his long academic career, Prof. López-Cajún gave mainly courses on Mechanics of Transmissions and Mechanism Design, both on basic formation and advanced topics for bachelor, master, and Ph.D. students at the most in his university but also with invited lectures and seminars abroad all round the world.

He was also interested in many other subjects of MMS in which he also gave many other courses always with special attention to Mechanism Science even in the fields of Robotics, Automation, diagnostics of machinery, and History of mechanical engineering. This last was his passion outside of regular teaching frames but he always tried to give history hints in his lectures to make the students aware not only of the past efforts and invention but to show that the advances in technology and particularly in MMS are due to the efforts and dedication of persons, inventors, academics and professionals, during several years of works.

In particular his passion and clarity in teaching together with his kindness and humanity made him as a very appreciated teacher by the students among them he is still remembered also as a great teacher. In his teaching activity he was well dedicated not only in lecturing but also in assisting the students with tutorials and meetings for better explanation of the subjects helping the students to have a clear understanding of the concepts with a practical application with numerical examples if not possible experimental practice. His attitude made him like a father for those who were in strict relationship with him because of thesis projects and even more as Ph.D. students. He was also well open to share his teaching with plans to combine his lectures, regular or invited, with lectures by other colleagues with the aim to give experience to students to appreciate not only the local teaching but even to learn topics with different viewpoints and cultural backgrounds. With the students he was never aggressive, and he always tried to accommodate the students to have the time for their understanding, although at the time of exams he was rigours and objective in the evaluations.

While being Profesor Universidad Autónoma de Querétaro he was living in Queretaro where he was taking care of his nephew who lost both the parents quite early so that he could not make his own family. But then in 2008 he got married with Maria Agueda Amador after many years of relationship with her. At their wedding Prof. López-Cajún wanted to have his friends from IFToMM eve as weeding wisdom as a sign of the IFToMM spirit that the IFToMM community is like a family. In Fig. 3 the photo shows the just married Carlos and Maria together with Ineke and Teun Koetsier (from Netherlands), and Brunella and Marco Ceccarelli (from Italy).

The participation of colleagues from the IFToMM community in his marriage is emblematic to indicate the spirit of Prof. López-Cajún of how to live and participate in the IFToMM community by combining technical-scientific activities with social relationships that undoubtedly improve and give satisfactions of long-term personal sociality in such collaborations, including international ones.

With this attitude of personal involvement, was an effective promoter of aggregation in various national and international contexts. This communicative capacity and sharing of community aggregation was also carried out with cordial meetings around a table during a lunch both in congress and non-congress environments. Figure 4 shows an example of such meetings in which the Prof. López-Cajún brought together Mexican colleagues also including his former Ph.D. students now professors, together with fellow foreign visitors, both to discuss and plan greater incisiveness of the Mexican community in the national academic and research programs as to plan adequate participation and visibility in international frames, especially in IFToMM.

**Fig. 3** Wedding memory photo of Carlos López-Cajún and Maria Agueda Amador with Ineke and Teun Koetsier (at their right) and Marco and Brunella Ceccarelli (at their left)

**Fig. 4** A meeting organized by Prof. Carlos López-Cajún with Mexican colleagues in Mexico City in 2018 (from the left to right: Carlos López-Cajún, Marco Ceccarelli—invited guest, Eusebio Hernandez and Ivan Valdez from IPN-Ticoman, Mario Acevedo from Panamericana University, and Prof. Christopher Torres from IPN-Zapeteco

Within his activity it is to note his strong actions as promoter of IFToMM Mexico, beside being a very active member of ASME. In Mexican national frames he was a Founder Member of the Mexican Society of Mechanical Engineering (SOMIM) as a national aggregation of a community well recognized within Mexico and abroad.

Because of his reputation was appointed a member of the Mexican Academy of Engineering and awarded with several honors by local, national, and international institutions, among which it may be highlighted the Mexican National Researcher award.

Prof. López-Cajún had an intense international activity with regular and continuous participation not only in congress events but also in promotion and management of activities of international community institutions. As an ASME member he has been very active in participating in international congresses in the American continent and in the activity of the association. As a member and co-founder of SOMIM he has always been active and proactive in the growth of the community both academically and professionally with interactions at international levels. But the most significant activity was carried out within the IFToMM, International Federation for the Promotion of Machine and Mechanism Science, since the beginning of his academic career, evolving from simple participation in congresses to leadership roles.

He served IFToMM as Chair of Mexico IFToMM member organization, member of the Permanent Commission on History of MMS, member of the Executive Council and also as Secretary General in 2008–2011. Moreover, he proposed and contributed to the organization of the 13th IFToMM World Congress held at Guanajuato, México in 2011 and he also was Chair of the HMM2016 Symposium on History of Mechanism and Machines held at Querétaro, México in 2016.

Prof. López-Cajún was recruited for the Commission for History of the MMS during the 1999 IFToMM World Congress in Oulu, Finland, by Teun Koetsier and Marco Ceccarelli, past and current Chair of the Commission (Ceccarelli and Koetsier 2004; Gasparetto and Ceccarelli 2022), having appreciated his interest and vision on the history of mechanical engineering as also important in the training of a modern engineer and researcher in MMS fields. Since the first days of his appointment as a member of the commission, the Prof. López-Cajún has been active and reactive by participating in the activities both in meetings and interactions, also through media and Internet, and in the specific research and interpretation of inventions, events, and personalities in the history of mechanical machinery. In fact, it has always contributed since the first HMM symposium with significant contributions that have always received great attention from the participants and subsequently from the experts of the subject in finding documentation and published works.

Figure 5 shows examples of his participation in the commission's statutory meetings during which the made substantial contributions in the discussion of the commission's issues and plans to meet the IFToMM constitutional requirements for the commission's activities but also to promote a greater incisiveness of the commission with a wider international participation of colleagues (fundamental characteristic of the commission) not only from the member organizations of IFToMM but also from other communities interested in the history of the machines. In this active participation in the meetings of the commission as well as in the work of the HMM symposium, Prof. López-Cajún has also established relationships and collaborations at an international level, promoting the interest in the history of mechanical machinery by also young researchers in MMS areas. In particular, his works presented and published in the HMM symposium range from historical and interpretative studies of machines also of the recent past to theoretical and design analysis for the reconstruction of machines not only coming from the history of Mexican technology.

This continuous and prolific activity on the history of mechanical engineering also saw him as an always present actor also in the activities of the commission's

a)



b)

**Fig. 5** Examples of participation of Prof. Carlos López-Cajún in the meeting activities of the IFToMM PC for History of MMS: **a** PC meeting in 2000 during HMM2000 symposium in Cassino, Italy; **b** PC meeting in 2011 during IFToMM World Congress in Guanajuato, Mexico

Workshop which was proposed precisely as a meeting frame to stimulate collaborations and research on local aspects and personalities that were not known or not sufficiently detailed for an international awareness. Figure 6a documents the participation of Prof. López-Cajún in the 2004 Workshop in Dresden, Germany, in which, among other things, the commission started an initiative to attract attention from wider communities, even from a general public to the cultural heritage that mechanical engineering has produced in the past in terms of models and technical-experimental documentation for training and teaching. Figure 6b shows an example of the cordial interaction that Prof. López-Cajún established to start friendly collaborations and partnerships referring to his last attendance at the HMM symposium in 2018 with a convivial meeting with his friend and colleague Prof. Baichun Zhang, organizer of the symposium in Beijing, China.

One major contribution of Prof. López-Cajún in the activities of the Permanent Commission, after having actively participate to all the HHM symposia since the beginning 2000, was the organization of the 2016 HMM symposium in Queretaro, as also in his capacity of member of the scientific committee for HMM. The 2016

**Fig. 6** Examples of participation of Prof. Carlos López-Cajún in the activities of the IFToMM PC for History of MMS: **a** PC Workshop 2004 in Dresden, Germany; **b** meeting with Prof. Baichun Zhang in Queretaro during HMM2016 symposium

Symposium was very well participated with 23 papers presented by authors from all around the world and published in the Springer book series on History of MMS (López-Cajún and Ceccarelli 2016). The program was organized also with a very interesting social cultural program, as in the tradition of the HMM symposia, that permitted the participants to strengthen or start their friendship with more plans of collaborations that gave results in more findings in history of machines and mechanisms with better technical characters as per the engineering background of the HMM symposium community.

Prof. López-Cajún worked a significant role in IFToMM in different positions, staring as simple IFToMMist since he participated in the IFToMM activity initially in the thematic congresses and mainly in the world congresses that have allowed him to know the institutional and operational characteristics of the IFToMM community as well as to know members of this community. After being an active member of the IFToMM Member Organization Mexico, he was elected President of it in 1999, activating for a greater participation of Mexican colleagues in the IFToMM technical committees and mainly giving a more international breath to the Mexican community referring to the Mexican association of mechanical engineering SOMIM of which he was also vice president as well as a founding member. In this promotional activity of the Mexican community, it should also be remembered its commitment which led to the proposal to host the IFToMM World Congress in 2011 in Mexico which was well accepted by the IFToMM General Assembly in 2007 as programmatic in allowing direct experiences of the surrounding communities. Initially, the proposal agreed within the Mexican community was to host the Congress at the University of Querétaro, the seat of Prof. López-Cajún who, after having quickly checked the efficiency and the possibility of suitable infrastructures (a large convention center promised in Queretaro was postponed by the Mexican local government), was able to involve his Mexican colleagues to find an optimal solution in the city of Guanajuato, with characteristics of social and tourist attractiveness combined with a network of surrounding technical universities to which the University of Querétaro also referred. Even though he was part of the organizing committee, the professor left the responsibility of organizing the Congress to the president of the Mexico IFToMM Member Organization of the moment Professor Riccardo Chicurel with a committee composed of members also from nearby universities. However, his active participation and interest in successfully planning the 2011 IFToMM World Congress led him to a continuous commitment and presence as shown in the example in Fig. 7.

Thus, with the experience of participation at all levels and therefore of leadership as Chair of an IFToMM Member Organization, Prof. López-Cajún was then elected a member of the IFToMM Executive Council for the 2003–2007 term, making significant contributions to the improvement and growth of the IFToMM activities, with regular participation in the meetings of the IFToMM Executive Council chaired by Professor Kenneth Waldron, Fig. 8.

During this period Prof. López-Cajún coordinated well with the members of the IFToMM Executive Council, receiving appreciation and recognition for his commitment and results in promote IFToMM especially in the South American world, also involving the Iberoamerican Federation of Mechanical Engineering FebIM which

**Fig. 7** Meeting for planning the 2011 IFToMM World Congress on 23 September 2010 (from the left): Adolfo Pamanes, Marco Ceccarelli Ricardo Chicurel, Juan Carlos Jauregui, and Carlos Lopez-Cajun

**Fig. 8** Meeting participation of Prof. Carlos López-Cajún as EC member at the meeting of the IFToMM Executive Council in 2005 in Besancon, France

in those years established a bilateral agreement with IFToMM to activate concrete collaborations in synergy. A first result of this agreement should be remembered in the activation of the MUSME Congress sponsored by both federations on the issues of Multibody Dynamics and Mechatronics, which began in 2002 in Mexico City. In this context, the two federations also shared the activities of their technical committees on Robotics and Mechatronics, being Prof. López-Cajún the liaison person for many years.

The interest and dedication of Prof. López-Cajún have given results of appreciation so much so that at the General Assembly of the IFToMM in 2007 he was unanimously elected General Secretary of IFToMM by the present Chairs of the IFToMM member Organizations. He carried out this position with continuous and regular activity with efficient coordination with the president Marco Ceccarelli and the treasurer Joseph Rooney who, together with the past president Kenneth Waldron, formed the Presidential Desk which coordinated the activities of the IFToMM Executive Council, also gathering the enthusiastic participation and contribution of all its members. These activities and the relative results are summarized in numerous documents which are mainly archived at the IFToMM archive at the CISM in Udine, Italy, and by the publications (López-Cajún 2008–2011; Ceccarelli et al. 2011; Ceccarelli 2013, 2022) which give a synthetic summary.

As General Secretary, Prof. López-Cajún carried out fully and with excellent results also recognized in the final report presented at the 2011 IFToMM General Assembly during the World Congress in Guanajuato, Mexico, regarding his constitutional tasks as a point of reference for the management of IFToMM affairs, editor of the official documents of the IFToMM, manager of relations and communications with the bodies (PC, TC, Chair of GA) of the IFToMM and with the IFToMM community in general, and collaborator of the president in coordinating the activities and above all in presiding over the meetings of the Executive Council in presence and in telematic form.

Figure 9 shows the group photos at the end of the Executive Council meetings with the participation of all the members of the Executive Council and some other officers of the IFToMM as chairperson or representatives of the technical and permanent commissions as well as Chair and representatives of the Member Organizations. As can also be noted from the photos Prof. López-Cajún has always carried out his duties as secretary general with discretion and never without exaggerating in a leading role but leaving plenty of space, in agreement with the president, for the discussion of those present at the meetings and also as can be seen from the photos giving a greater visibility to all the representatives of the IFToMM bodies.

In Fig. 9a the meeting held at Waseda University, in Tokyo, Japan, with professor Atsuo Takanishi (last on the right), local organizer, is documented, with the aim of giving greater international visibility to IFToMM on the occasion of the Executive Council meetings, with the possibility also for the young Japanese researchers to be able to attend the discussions and the planning of the activities. This approach continued throughout the mandate as documented by the fact that the Executive Council meeting was held with the prescribed annual regularity, being hosted in the various continents where the IFToMM has Organization Members.

Figure 9b shows the meeting held in Mexico at the site of the Congress of 2011 as required by the constitutional requirements in the duty of the Executive Council in its collegiality to verify the organization in the World Congress and the structures provided for it. Prof. López-Cajún on that occasion was particularly involved being also in the organizing committee and remembering that he was the proponent of this Congress. In this role he has made a considerable commitment which ensured, together with the congress organizers, a success, as expected, at the 2011 Congress with appreciation already during the 2009 visit. On this occasion in 2009, it was also possible to celebrate the fortieth anniversary of the IFToMM with an event limited to a single day and a few interventions by the past presidents and the few founding fathers still alive. Thanks to the organization of Prof. López-Cajún, the ceremony took place at the historic site of the University of Guanajuato with contributions also online by guests from all over the world with an efficient coordination by Prof. López-Cajún.

Figure 9c shows the meeting that was held at the University of Sousse in Tunisia as the first event of the IFToMM official body on the African continent and at the same time at a recently affiliated Member Organization. The local organizer Professor Lotfi Romdhane (third form the left) with the Rector (near him) enthusiastically welcomed the IFToMM delegation composed of the Executive Council members and other IFToMM officers, also proposing an interesting social program with an excursion to the neighboring territory to learn about the culture and history of the country with visits also to archaeological sites from the Phoenician, Roman, and Arab eras. Figure 9d shows the group photo of the official meeting of the executive council at the beginning of the 2011 World Congress with a program that included a second session at the end of the Congress to allow the new Executive Council to share discussion, problems and programming between the two bodies to ensure continuity


**Fig. 9** Examples of participation of Prof. Carlos López-Cajún in the meeting activities of the IFToMM Executive Council: **a** in 2008 in Tokyo during CISM-IFToMM Romansy Symposium; **b** in 2009 in Guanajuato, Mexico, checking the 2011 World Congress site; **c** in 2010 in Sousse, Tunisia; **d** in 2011 during IFToMM World Congress in Guanajuato, Mexico

in the guidance of the IFToMM. In this last aspect Prof. López-Cajún together with the president collaborated closely especially in the early days with the new general secretary Veniamin Goldfarb and with the new president Yoshiko Nakamura to allow them to have a regular and efficient performance of their activities in their mandate 2012–2015.

Figure 10 shows examples of the management of Executive Council meetings in which Prof. López-Cajún carried out his role with great efficiency also in complying with the timing of a timed agenda with a high density of topics to be discussed. He can be noted in Fig. 10a while recording the interventions alongside the treasurer and the president. In Fig. 10b Prof. López-Cajún at the center of the coordination table between the president and the treasurer coordinates the interventions assisted with multimedia systems and projector allowing interventions also online for those who had not been able to come in attendance. Also noteworthy is Prof. López-Cajún's ability to coordinate with an open and understandable language to all listeners from all continents and also with different linguistic skills in sustaining conversations and discussions in English as prescribed by the IFToMM constitution.

Figure 11 shows moments of the activities that Prof. López-Cajún following the meetings of the Executive Council with photographic indication of the aforementioned precision and scrupulousness in carrying out the institutional tasks envisaged in his role as secretary general. Figure 11a shows the presidential desk meeting, also

a)

b)

**Fig. 10** Prof. Carlos López-Cajún as IFToMM Secretary General, recording the discussion at the meeting of EC meeting: **a** in 2008 in Tokyo after CISM-IFToMM Romansy Symposium (first in the left); **b** in 2011 during IFToMM World Congress in Guanajuato, Mexico (at the center of chair desk)


**Fig. 11** Prof. Carlos López-Cajún at work as IFToMM Secretary General: **a** in 2011 meeting of the Presidential Desk during IFToMM World Congress in Guanajuato, Mexico; **b** in 2007 preparing documents for EC meeting with the IFToMM President; **c** in 2011 revising the minutes of the 2011 EC meeting with the IFToMM President

held in a convivial form, to adequately prepare an Executive Council meeting with a preliminary view shared by the members of the presidential desk to efficiently deal with all discussions and issues not only included in the agenda. In this task Prof. López-Cajún has played an important role, always being punctual in the preparation of the agenda points but also in the cordiality of the discussion of each point even in critical terms. In Fig. 11b and c, on the other hand, moments of work with the president are reported in order to better take care of the drafting of reports and official documents following not only the meetings of the Executive Council but also to produce suitable and complete documents for the IFToMM archive as well as prescribed by constitutional obligations, but also for an awareness of the importance of maintaining a historical memory of the activities and their evolution.

Prof. López-Cajún was member of several scientific committees for international conferences and journals as result of his reputation from an intense scientific activity that is documents by papers, books (for teaching and with research results), and patents. Significant are the book on Cam Transmissions (Angeles and López-Cajún 1991), co-authored with Prof. Jorge Angeles and the book on Mechanism Design (in

Spanish) (López-Cajún and Ceccarelli 2008), coauthored with Prof. Marco Ceccarelli. He contributed to many projects in different topics, beside Mechanism Design, like in Robotics, Biomedical devices, Space systems, and History of Engineering and Machines with achievements in highly disseminated publications, that can be still easily found (not only in Google).

Throughout his life, Prof. López-Cajún has combined professional scientific activity, characterized by dedication and intelligence, with an aptitude for relating to people, be they students or fellow researchers, with an empathy that has made his figure attractive both on a scientific and didactic level, leaving an imperishable memory of his spirit and his results both in scientific and social relations.

## 2 List of Main Works

The prolific scientific activity of Prof. López-Cajún covered many aspects of mechanical engineering and especially in the areas of MMS with particular interests and significant results especially in analysis and synthesis of mechanisms, cam transmissions, design of service robots, machine diagnostics, vehicle mechanics, vibration mechanics, and history of mechanisms and machine. The most significant contributions are documented in more than 500 papers (and still available not only in Google) that are published in international journals and international conferences with a significant number of citations by other authors documenting a significant impact in their respective thematic areas. Furthermore, significant contributions have been collected in book chapters and especially in co-authored books among which it is to note:

- Optimization of Cam Mechanisms del 1991 (Angeles and López-Cajún 1991), Fig. 12a
- Mechanisms (in Spanish) del 2008 (López-Cajún and Ceccarelli 2008), Fig. 12b

In addition, remarkable is the volume of proceedings of the 2016 HMM symposium on History of Machines and Mechanisms (López-Cajún and Ceccarelli 2016), Fig. 13, which the Prof. López-Cajún organized in Queretaro with a successful international participation and still today in of interest not only for investigators on the history of mechanical engineering as documented by the more than 20,000 downloads received to date.

From the very prolific publication activity reporting results ant their enhancements the following main papers listed in References can be indicated as representative of main works of Prof. López-Cajún on:

- mechanism design and cam transmissions: (Angeles and López-Cajún 1988; Angeles et al. 1994a, b, c; Carbone et al. 2001; Lanni et al. 2006)
- machine diagnostics and vibration mechanics: (Lozano-Guzmán et al. 1993; Rafael et al. 2009; González-Cruz et al. 2014, 2015; Figueroa et al. 2004)

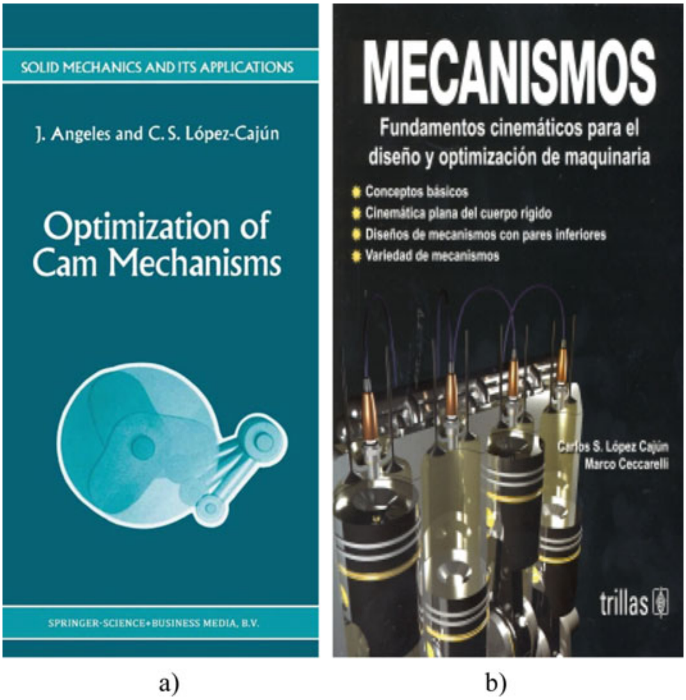



**Fig. 12** Books co-authored by Prof. Carlos López-Cajún: **a** with Jorge Angeles on Cam Mechanisms in 1991 (Angeles and López-Cajún 1991); **b** with Marco Ceccarelli in 2008 on Mechanism teaching (López-Cajún and Ceccarelli 2008)

- analysis and design of robots: (Angeles et al. 1988; Angeles and López-Cajún 1992; Hernández-Martínez et al. 2010a, b; Jáuregui-Correa et al. 2013, 2015; López-Cajún et al. 2015)
- history of mechanisms and machines: (Figueroa et al. 2000; López-Cajún et al. 2004; López-Cajún 2010)

However, during his long activity Prof. López-Cajún authored and/or coauthored more than 400 papers in international journals and conferences, most of them are still of reference and background for the last advances in specific topics.

## 3 Review of Main Works and Contributions

The main contributions by Prof. López-Cajún can be recognized mainly in mechanism design and cam transmissions, machine diagnostics and vibration mechanics, analysis and design of robots, and history of mechanisms and machines.

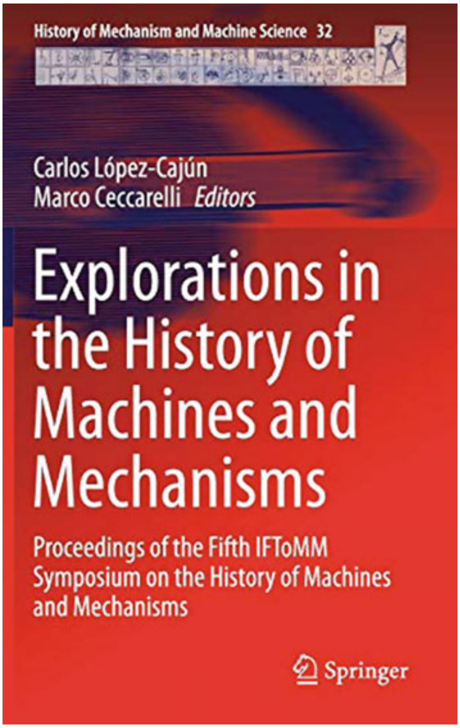



**Fig. 13** Proceedings volume co-authored by Prof. Carlos López-Cajún with Prof. Marco Ceccarelli on the 2016 HMM symposium held in Queretaro, Mexico (López-Cajún and Ceccarelli 2016)

In the following, examples and most significant aspects of those achievements are summarized using the original publications by Prof. López-Cajún.

Referring to mechanism design and cam transmissions, papers (Angeles and López-Cajún 1988; Angeles et al. 1994a, b, c; Carbone et al. 2001; Lanni et al. 2006) and the books (Angeles and López-Cajún 1991; López-Cajún and Ceccarelli 2008) can summarize the contributions of by Prof. López-Cajún in the main aspects of analysis and design aspects for procedures and solutions including activity of prototyping and testing for experimental validation.

Figure 14 from works in Carbone et al. (2001) and Lanni et al. (2006) summarizes the most significant issues in modelling for design and analysis. Figure 14a shows an efficient model for performance evaluation via simulation that can be used also in testing characterization and Fig. 14b the numerical results using the model. Figure 14a shows an example of the great synthetic modeling ability of Prof. López-Cajún in recognizing the fundamental aspects of transmission mechanics in cam systems, either fairly simple or very complex. The example refers to the generation of an equivalent slider-crank mechanism regarding a circular-arc profile. The same scheme can be used for analyzing any cam profile by using a circular arc as a corresponding portion approximated by the osculating circle at the profile point under evaluation. The equivalence of the slider-crank mechanism is valid up to the second order kinematic characteristics since the osculating circle describes second order

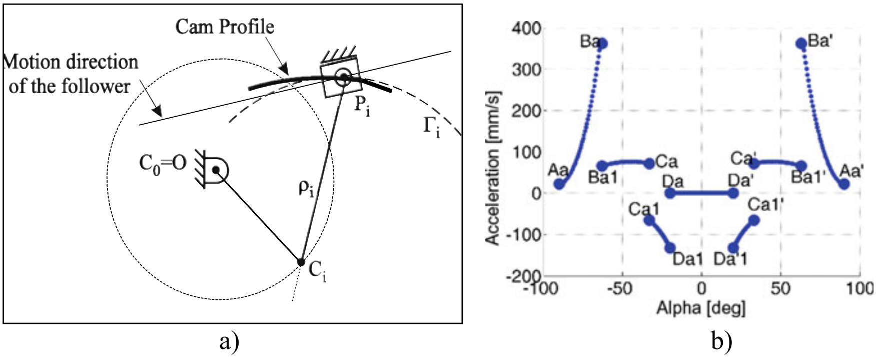



**Fig. 14** An illustrative example of kinematic analysis of the circular-arc cam transmission (Carbone et al. 2001; Lanni et al. 2006): **a** identification of equivalent slider-crank mechanism; **b** results of the kinematic analysis in term of point acceleration

contact with the osculated profile, for a proper straightforward kinematic analysis (López-Cajún and Ceccarelli 2008). The crank-slider mechanism can be determined by using the center Ci of the circle Γi and the direction of the follower motion as reported in Fig. 14a. In particular, the coupler link is determined as the link connecting the center Ci with the point Pi of the osculated profile and the crank is the link connecting the frame joint to the ideal joint at point Ci. Thus, the coupler length coincides with the radius ρi of the circular-arc. The equivalent mechanism method of analysis has two advantages: first, it permits the analysis of cams and follower of any form moving in any manner; then, it provides a pictorial concept of the relative movement of the members.

The method is applicable to any cam profile since a profile can be considered as composed of a series of small-length circular arcs that are related to osculating circles that can be identified by using normal lines to the profile to determine centers of curvature (López-Cajún and Ceccarelli 2008). Once the equivalent slider-crank mechanism is determined, the cam behavior can be analyzed by looking at the kinematics of the slider point of the slider-crank mechanism that is related to each circular-arc portion of the cam profile with results like those in Fig. 14b.

Similarly, Prof. López-Cajún proposed models that were very efficient for dynamic analysis and the transmission of forces in cam transmissions with procedures that were also implemented in research and experimental characterizations of the dynamic behavior of the cam transmissions as reported in the example of publication (Lanni et al. 2006).

Relevant contributions of Prof. López-Cajún in cooperation with other authors are reported in the works (Angeles and López-Cajún 1988; Angeles et al. 1994a, b, c) and in the book (Angeles and López-Cajún 1991) concerning procedures and design solutions for cam transmissions using algorithms of optimized design using the characteristics of the cams and their operational purposes.

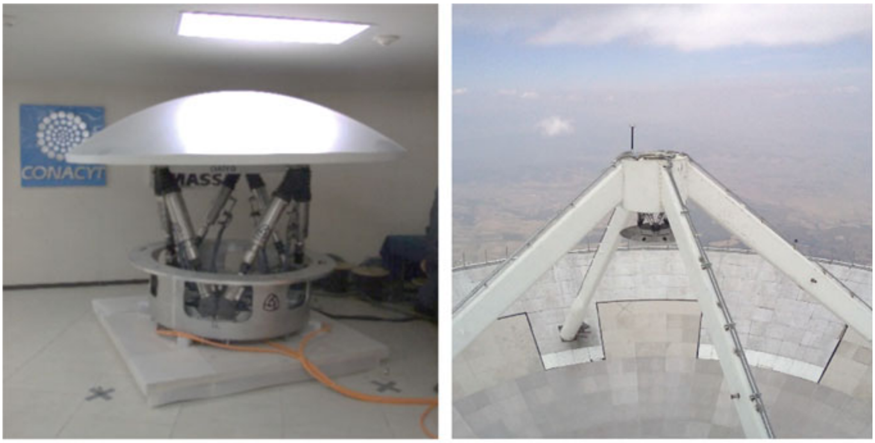
In the fields of machine diagnostics and vibration mechanics of several types of machine design including vehicles, prosthesis, and other machine aspects related to materials, papers (Lozano-Guzmán et al. 1993; Rafael et al. 2009; González-Cruz et al. 2014, 2015; Figueroa et al. 2004) give an overview of wide interest and achievements obtained also for practical implementations.

Referring to Vehicle Dynamics, Vibrations, and Complex Systems, the contributions of Prof. López-Cajún in the area of complex systems are the results of previous works on dynamics and vibrations. He noticed that to understand modern mechanical systems' dynamic behavior; it was necessary to include other disciplines. He explained multi-body dynamics as complex mechanical systems comprising many interconnected individual components. He assumed that these interconnections could be modeled as weak springs and dampers for explaining synchronization. In his publications, he proposed to analyze complex systems to understand the synchronization of different elements. This analogy allowed him and his coauthors to locate long-time variations by analyzing the coupling among different elements. One of the first attempts to analyze the effect of the surroundings was an experiment with 24 blades (static condition) subject to an axial airflow. The vibration motion was recorded with 24 accelerometers mounted on the tip of each blade. The experimental data were analyzed with the Kuramoto parameter, the correlation coefficients, the cross-correlation function, and the recurrence plots. They found that the foreground components determined the dynamic response of each blade, and the background conditions the coupling response. He and his coauthors also studied experimental data obtained inside an automobile. For the analysis, they applied various techniques, and the data were obtained through a set of accelerometers mounted on the dashboard and one door (González-Cruz et al. 2014, 2015).

His contributions to the analysis of vibration field data included also a methodology for determining horse movements. This analysis's results helped specify the required movements for designing a mechanism that emulates hippo-therapy for children. The data were obtained by setting accelerometers on horses and converting the data into planar and tilt movements (López-Cajún et al. 2015).

Regarding vehicle dynamics analysis, Prof. Lopéz-Cajún worked on several topics as in the following short summary. He also determined the effect of the type of suspension on the load carried by heavy trucks. He and his coauthors instrumented different vehicles with a data logger and a set of accelerometers and measured the vibration levels on the truck. They compared both suspensions and found that the air-spring suspension transmitted 48% of the vibration energy than the leaf suspension (Lozano-Guzmán et al. 1993). He also worked on optimizing the truck's fuel consumption by analyzing the powertrain system and optimizing the gear shift to operate the engine at its lower fuel consumption regime (Rafael et al. 2009).

One of his main topics of interest was Robotics. His contribution covered modeling, analysis, and practical applications. In this field, he has contributed to developing parallel robot kinematic and dynamic models. He gave a fundamental contribution to the development of the kinematic model of the parallel robot that controls the position of the secondary mirror of the Large Millimetric Telescope



a) b)

**Fig. 15** The designed parallel robot for the secondary mirror of the Mexican Large Millimetric: **a** the built unit; **b** installed in the large telescope

(famous up to be in https://es.wikipedia.org/wiki/Gran_Telescopio_Milimétrico, as a fundamental astronomic instrument installed in the Mexican State of Puebla), Fig. 15.

He also contributed to the determination of the pose accuracy considering joint individual errors and overall errors, as reported for example in Jáuregui-Correa et al. (2013, 2015). In this area, he also worked on estimating the end-effector pose errors of the cable-base manipulator Milli-Cassino Tracking System (Milli-CaTraSys), developed at LARM at the University of Cassino in Italy (Hernández-Martínez et al. 2010a). The results of this development were also applied for determining displacements and orientation variations of other robots, such as CaPaMan 2bis. To characterize the system, he and his coauthors made ADAMS simulations and experimentally validated the results as in Hernández-Martínez et al. (2010b).

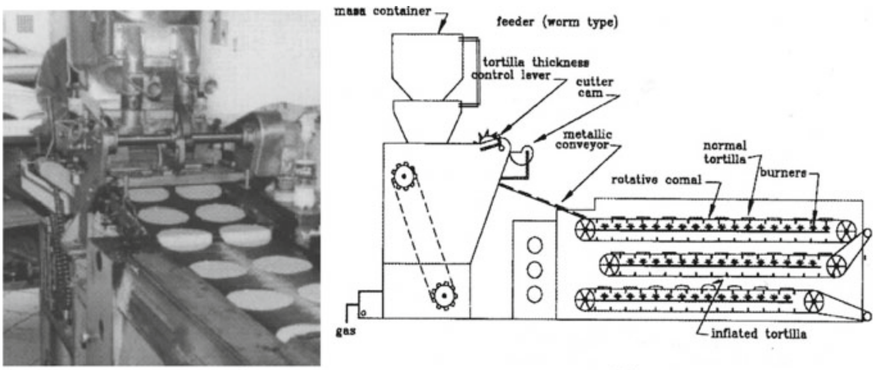
Regarding serial robots, Prof. Lopéz-Cajún defined the conditioning index in terms of the reciprocal of its minimum condition number, or other words, the condition number of its Jacobian matrix. The Jacobian quadratic norm is needed to determine the condition number. In the publication (Angeles and López-Cajún 1992), it was defined that a robot with a 100% conditioning index is isotropic, meaning that a robot with all its angles between neighboring revolute axes at 90° and all its distances between neighboring axes identical is isotropic. On the topic of serial robots, another important work was the paper dealing with trajectory planning (Angeles et al. 1988). In this work, they derived a systematic procedure in the configuration space by referring to the orientation of the end-effector to a unique orthogonal frame. The orthogonal frame was defined at every point along the end-effector's path. The Darboux vector and its time derivative determined angular velocity and acceleration.

He also contributed to revising the state of the art in robotic vehicle technologies and their implementation for monitoring road infrastructure, as results of several invited lecture on this and other topics.

The wide interest on history of mechanisms and machines of Prof. López-Cajún is summarized in the sample papers (Figueroa et al. 2000; López-Cajún et al. 2004; López-Cajún 2010) attaching the historical-technical analysis of a past machine and highlighting attention to past distinguished figures with the aim not only to record the past values but also to reevaluate the past achievements for a past-aware modern vision of further developments.

Figure 16 (Figueroa et al. 2000) shows the historical-technical study that Prof. López-Cajún made on the typically Mexican machine for the production of tortillas. The machine examined is a fairly recent machine but with a cultural and technical history that Prof. López-Cajún wanted to highlight as an example of how much a design and construction of a machine can hide or contain even in broader cultural aspects. The analysis carried out included the historical study of the tortillas and how they were produced as well as the reasons that led to the design of an automatic machine of which the one investigated is an emblematic example that he had available. The historical study of Prof. López-Cajún with his co-authors has deepened the motivations and the design choices as well as analyzed the functioning of the machine in functional terms related to the tortilla culture in Mexico.

The interest in the history of machines has led Prof. López-Cajún also to research and understand texts from the past that are the basis of modern mechanics. Together with a team of international authors as reported in the publication (López-Cajún et al. 2004) he rediscovered and reevaluated the classification of machines according to Monge's concepts by the two students Augustin de Betancourt and José María Lanz y Zaldívar (in short Lanz) of the Polytechnic school of Paris and among other things, he discovered that Lanz was a fellow citizen of Campeche. Therefore, this discovery gave him a further historical-technical problem to investigate which, together with the author of this chapter, in several years he tried to solve in relation to the personality of Lanz as defined finally in the publication (López-Cajún 2010). His passion was




a) b)

**Fig. 16** The automatic machine for production of Mexican tortillas investigated by Prof. López-Cajún with results in Figueroa et al. (2000): **a** the sample of the investigate machine; **b** a scheme of the historical-technical analysis not purely technical but also of wide-ranging culture and in fact on several occasions he met with the great-grandchildren of Lanz to better understand the life and the human and technical-scientific figure also with the intention of looking for a portrait (without being successful in this last search). Nevertheless, he managed to clearly delineate in López-Cajún (2010) the figure and the historical-scientific contribution of his fellow citizen of Campeche who, similarly to him in his technical-professional activities, was a citizen of the world having had activities and experiences in various parts of the world.

## 4 Legacy and Today Interpretation of Contributions

The legacy that Prof. Carlos López-Cajún left as a technical cultural heritage and teaching values as a reference for the next generations can be summarized mainly in three aspects:

- achievements of impact also for future developments in the aforementioned fields of his interest and activity
- methods of teaching and interacting with students
- sociability with kind character open to consolidate scientific-technical collaborations and to promote greater aggregation and dissemination of the importance of a technical-scientific community

The impact of the results obtained from the technical-scientific activities of Prof. López-Cajún are still today a reference for the community not only for the specific results obtained which have advanced knowledge and specific applications in the subjects of mechanisms, cam transmissions, machine diagnostics, vibration technology, applied biomechanics, robotics in mechatronics fields, and a historical awareness of the past, but also for the methodologies and approaches used to reach them with an engineering vision with characteristics of dissemination to wider areas. The attitude of Prof. López-Cajún is also significant in trying to disseminate the results of his research and design activities with presentation of activities and with a non-aggressive attitude, typical of today, with a spasmodic and excessive interest in citing his own works. In fact, an important aspect of the legacy that left us also consists in the fact that the further dissemination of the results, published in important and appropriate editorial frames, can be obtained through presentations and contacts with specific interested communities without the spasmodic attention and production of a valorization through indexes and citations obtainable through informatic means. Prof. López-Cajún has always given considerable importance to direct interaction that can allow not only a faster understanding of the results but also a subsequent if not immediate participation in further developments.

No less unforgettable are the events, facts, collaborations and interactions that Prof. López-Cajún lavished on the IFToMM community, making him a reference figure also for future generations, having fully embodied the original spirit of

IFToMM in the mission of promoting the science of the machines of the mechanisms not only for the improvement of technology but mainly for the well-being and peace in human society.

The legacy left by Prof. López-Cajún in the field of teaching and academic training is evident above all from the good memory that students and those who have had the opportunity to have the professor as mentor or supervisor for a long time. As already mentioned, of reference and therefore a legacy is the attitude with which Prof. López-Cajún transferred his knowledge in teaching with passion and dedication, paying attention to that students were attracted and made their own the attention required to what was discussed in the lessons. Another aspect of reference for the future is also the kindness in the interaction with the students or with those who collaborated with Prof. López-Cajún in the activities of mutual transfer of results and problems.

The aspect of empathy in carrying out the activities of his academic and scientific commitment is even more an aspect of inheritance on a social and personal level that makes Prof. López-Cajún a reference to be indicated for a correct attitude in the academic world and in society in general in order to ensure dignity to the activities of a community to which one refers without excessive self-centeredness. Still appreciable are the kindness and open-mindedness with which Prof. López-Cajún used to interact and accept new scientific and technical challenges but also to work involvement and collaboration with colleagues with different technical formation and even with a different cultural background coming from distant geographic locations. In this Prof. López-Cajún well embodied the spirit of the IFToMM which sees no barriers of any kind except the technical-scientific problems to start and sustain collaborations that can be useful for mutual cultural and technical growth as well as for the promotion of areas and structures that are less capable or less structured, also due to lack of funds.

Prof. López-Cajún had great teaching skills, he taught many years and every student remembered him as an excellent teacher. When his former students knew he passed away their expression was: “Oh, what terrible sad news! He was a great teacher and I will always remember him…”.

In conclusion, Prof. Carlos López-Cajún will be remembered as a distinguished figure with multifaceted skills and significant results of activity not only in the history of IFToMM and of the disciplinary areas of Mechanisms and Machines Science.

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# Jack Raymond Phillips (1923–2009)

**Gordon R. Pennock**

**Abstract** Jack Raymond Phillips was one of the founding fathers of IFToMM in 1969, (the acronym, at that time, for the International Federation for the Theory of Machines and Mechanisms). As a council member during the dark days of the Cold War, Jack toured Eastern Europe on a regular basis to keep the Federation intact when travel between the East and the West was all but impossible. It was his extraordinary character that helped IFToMM mature into the truly international scientific union that it is today. Jack was the inaugural chair of the IFToMM permanent commission for the history of mechanism and machine science which was established to promote the republishing of classical works of reference and the collection and circulation of material and information in the field of mechanism and machine science; to maintain the archive of the federation; and to promote activities and works in this field. Jack believed that an appreciation of the history of the discipline was essential for building the identity of the federation. His significant contributions to IFToMM were recognized in 1999 when he was elected an honorary member joining only ten other individuals to be so recognized at that time. Jack was honored again by the federation when, in 2004, he received the IFToMM lifetime service award.

## 1 Biographical Notes

Jack, see Fig. 1, was born in Geelong, Victoria, Australia, on July 18th, 1923. As an undergraduate student during most of World War II, Jack studied mechanical engineering at the University of Melbourne, obtaining a B.Mech.E. degree, and for two years served as an engineering Lieutenant in the Australian Army. Towards the end of the war, he was involved among other things with repairing and adjusting the various kinds of front wheel suspensions and steering linkages of army vehicles. This work afforded him the opportunity of a practical knowledge of spatial mechanisms. Afterwards, he was for a short time a teacher in various areas of mechanical

G. R. Pennock (✉)
School of Mechanical Engineering, Purdue University, West Lafayette, IN 47907, USA
e-mail: pennock@purdue.edu



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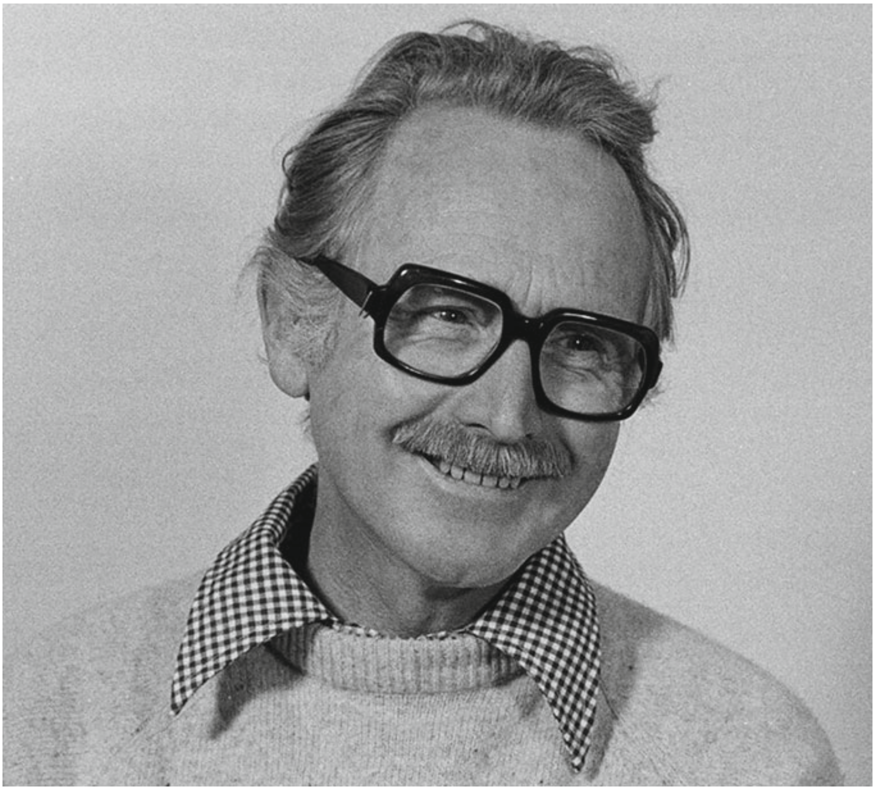

**Fig. 1** Jack Raymond Phillips (circa 1978)

engineering including planar linkages, dynamics of machinery, balancing, and planar involute gearing. For a three-year period, during the late 1940s and early 1950s, Jack was a machine design engineer in packaging machine development, then works engineer with the Imperial Chemical Company (ICI), in Great Britain. Throughout this period, Jack was a somewhat irregular worker of various kinds who struggled with the general idea that there was much more to real machinery than planar mechanics.

Back again in Australia in 1953, Jack worked to understand the statics of the multi-furrow trailed disc plough. This unwieldy apparatus, like a sailing yacht or an asymmetrical rigid body hung up on three light flexible cables, had no plane of symmetry. The balanced system of external forces acting upon the steadily traveling plough could not be reduced to a planar system without departing unreasonably from reality. One is thereby led to discover, as Jack did, that four pure forces acting on a rigid body in equilibrium will always reside upon four generators of the same family of a hyperboloid. The lines of action of any three of the four forces determine the hyperboloid, and the magic is that the fourth force is constrained to act along some other generator of the said, same hyperboloid. The polygon of forces, a skew quadrilateral, closes; but there are often as well, as there are in the cases of the plough and the yacht, couples extant, and these must be accounted for.

Jack wrote his first technical paper (Phillips 1955) on the graphical manipulation of skew forces and couples having become aware, rather belatedly, of Möbius (1837) and Plucker (1868). However, Jack was totally unaware at the time, that he was groping about in what for him was the wilderness of Ball's three-system of screws (Ball 1900), and that, already established therein, was the pitch quadric (the hyperboloid of zero-pitch screws). Jack had, in the dark as it were, bumped into the pitch quadric (Ball 1900; Joly 1902–1904) by good fortune. An early figure of the plough and the associated pitch quadric, from his research work in 1955, is reproduced as Fig. 10.05 (§ 10.23) in his first book on the freedom in machinery that was published in 1984 (Phillips 1984). The two sets of four balanced forces on the chassis of the tractor and the chassis of a trailed disc plough are shown in Fig. 2. More will be said of Jack's two books in Part 3 of this chapter.

From 1953 until 1958 Jack was a graduate student at the University of Melbourne working on his doctoral dissertation (Phillips 1957) which focused on the mechanisms of the trailed disc plough. Towards the end of his doctoral work Jack became acquainted with the Englishman Kenneth H. Hunt (Pennock 2020) who had moved to Australia in 1949 and accepted a lectureship in Mechanical Engineering at the University of Melbourne in Parkville. Hunt was quickly promoted to Senior Lecturer, a position he held for some ten years before his appointment in 1960, as the Professor of Mechanism in the Department of Mechanical Engineering, at Monash University in Clayton. He was also appointed the Foundation Professor of Engineering which was a new position in this new university. From 1961 until 1975, Hunt was the inaugural Dean of the Faculty of Engineering and then Chair of Mechanism from 1976 until 1985. He is also remembered as the scientist who rediscovered Ball's theory of screws and who made significant contributions to screw system theory which

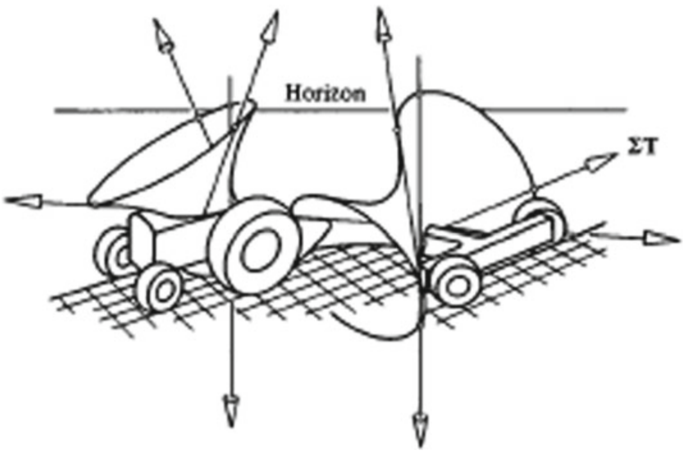


**Fig. 2** Two sets of four balanced forces on the tractor and the trailed disc plough

he applied to the kinematics of spatial mechanisms, universal shaft couplings, and robotics. He authored two classical books *Mechanisms and Motion* in 1959 (Hunt 1959) and *Kinematic Geometry of Mechanisms* (Hunt 1978) in 1978. Then in 2004 he co-authored (with Joseph K. Davidson) the more modern text *Robots and Screw Theory: Applications of Kinematics and Statics to Robotics* (Davidson and Hunt 2004). Hunt was also one of the founding fathers of IFToMM—the International Federation for the Theory of Machines and Mechanisms. (In 1998, the official name was changed to the International Federation for the Promotion of Mechanism and Machine Science.) The federation was officially born in 1969 and Hunt served on the first Executive Council from 1969–1971. He made important contributions to the foundation act with the initial member organizations and served as the founding chairman of the Australian Committee of the federation.

At the time of their first meeting Jack and Ken were cogitating the freedoms inherent in mechanical joints and the mobility of four-link closed loop mechanisms. Together they became aware of the works of Grübler and Kutzbach (Grübler 1883, 1885; Grübler and Getriebelehre 1917; Kutzbach 1933) and their combined enthusiasm for the kinematics and enumerative geometry of spatial mechanisms flourished as a result of their relationship. After completing his Ph.D. degree in 1958, however, Jack moved some 4,000 km west from Melbourne to Perth and joined the University of Western Australia. That same year, Jack presented a conference paper (Phillips 1958) on some mechanics problems that he encountered in designing a disc plough. His work with the disc plough resulted in a study of the mechanics of the driven or braked oblique-rolling vehicular wheel (Phillips 1959). See also Fig. 10.16 in reference (Phillips 1984). This led to more work in the area of kinetostatics and naturally into the beginnings of his understanding of the screw product and the reciprocity of two screws. Jack had perceived that the product of the wrench from the ground on the oblique-rolling vehicular wheel and the rate of twisting of the wheel with respect to the ground was the power loss at the contact patch. Jack's paper on a brief description of the six-component oblique-rolling wheel machine (Phillips 1961) was written at the University of Western Australia. The apparatus that is described in this paper, heavily dependent for its principles upon Jack's earlier work, was built in one of the university laboratories. Professor James Trevelyan, former Discipline Chair for Mechatronics at the university, recalls that he studied mechanical engineering at the university enmeshed in the complexities of the machines that remained there long after Jack had accepted his next position at the University of Sydney. Jack was also deeply involved in experimental agriculture, in the design, construction, and testing of newly developed subterranean clover seed harvesting machinery required to work across newly ploughed virgin land in semi-arid wheat country, where the safety of the spatial articulations and complicated mechanical movements of the clumsy machinery were of vital importance. Also, during this time, while in continuous correspondence with Hunt, they were working on the distribution of the available screws within mechanical joints having two and more degrees of freedom.

In June 1962, Jack stumbled upon a treatise on the theory of screws that was published in 1900 by the Irish astronomer, mathematician, and scientist Sir Robert Stawell Ball (the Lowndean Professor of Astronomy and Geometry at Cambridge

University, England, from 1892 until his death in 1913). This treatise on screw theory had been hiding among some other books, on the shelves of the General Library at the University of Western Australia, only 200 m away from the laboratory where Jack was working. Ball had been waiting there many years for the arrival of such an astute kinematician. It was with immense excitement that Jack read the work on the reciprocity of screws and the geometry of the cylindroid (also known as the Plucker conoid). Figure 3 shows the cylindroid generated by a spatial gear set where the speed ratio determines which generator of the cylindroid becomes the pitch line, see Fig. 22.03 in §22.20, page 182, of reference (Phillips 1984).

With their newly acquired knowledge of screw theory, Phillips and Hunt published their landmark paper on the theorem of three axes in the spatial motion of three rigid bodies (Phillips and Hunt 1964). Their work was an extension of the Kennedy-Aronhold theorem of three instantaneous centers of velocity for a pair of rigid bodies that move relative to each other in a single plane or in parallel planes. Their paper investigated the geometry and kinematics of instantaneous spatial motion generated by a pair of axodes and the relative spatial motion of three rigid bodies using the instantaneous screw axis (that is, an axis about which one rigid body is rotating about and translating along with respect to another rigid body). The paper documented the properties of the instantaneous screw axis and was a major contribution to our

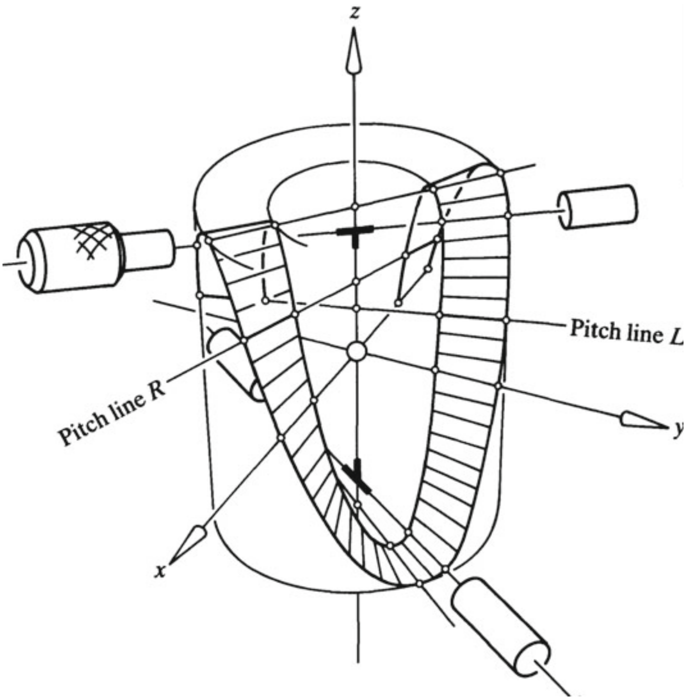


**Fig. 3** The cylindroid generated by a spatial gear set

understanding of the geometry and instantaneous kinematics of spatial linkages. Algebraic equations which are suitable for the design and kinematic analysis of spatial mechanisms can be derived from the work of Phillips and Hunt. Their collaboration on a textbook was an ongoing activity for several years. The work was very productive but slow since the interaction was by ordinary airmail and due to several disruptions, the book became the sole possession of Hunt. With hints from the earlier perceptive work of Ball, Hunt definitively worked out and clearly presented all of the six screw systems in his classical work on the kinematic geometry of mechanisms. The sections in the book that deal with the six screw systems constituted, in Jacks' opinion, the main enormous contribution of Hunt to our store of knowledge. The two books written by Jack on the freedom in machinery, see the following section, would appear somewhat later, the material having had the advantage not only of Ball and of Hunt but of a longer period of gestation.

In January 1963, Jack moved from the University of Western Australia to the University of Sydney accepting a position as an Associate Professor in the Theory of Machines in the Department of Mechanical Engineering. One of the students taking Jack's graduate level course on the kinematics of mechanisms was Kenneth J. Waldron. Ken received his Bachelor of Science degree in engineering in 1964 and was a research student from 1964–1965 studying for a Master of Engineering Science degree. His research activities focused on the general problems of constraint and mobility of linkages and was the beginning of some important contributions by Ken to the constraint analysis of mechanisms using the properties of screw systems. From 1965 to 1968, as a Research Assistant in the Design Division of the Department of Mechanical Engineering at Stanford University, California, Ken applied screw system theory, as reformulated by Phillips and Hunt, to study the instantaneous screws associated with single-degree-of-freedom spatial mechanisms. His doctoral dissertation applied screw system theory to a study of the mobility of linkages and he generated a number of new types of overconstrained linkages from the geometries of the relevant screw systems. Ken was awarded a Doctor of Engineering degree by the University of Sydney in 1999 and served two terms as President of IFToMM from January 1st, 2000, until December 31st, 2007.

Jack and his colleague Arthur Sherwood were responsible for the Kinematics course in the Department of Mechanical Engineering. Jack presented the analysis part of the course, focusing on the study of freedom and constraint and the methods of velocity and acceleration analysis of mechanisms. Arthur concentrated on the synthesis part of the course, namely the methods of designing new mechanisms that satisfy specified design criteria, for example, the coupler point of a four-bar linkage that could trace a trajectory through a number of specified points. The teaching of kinematics continued in this manner for more than three decades, always including the use of physical models of linkages and mechanisms and with an emphasis on geometrical approaches to the analysis and synthesis. The kinematics laboratory in the Department was renowned for the large number of models of working mechanisms and models that represented some theoretical or geometric principle. Numerous undergraduate thesis students and postgraduate students designed and constructed mechanisms and pieces of machinery that formed part of their research projects and would later become models on display in the laboratory. By the time Jack retired there was a large number of cupboards filled with unique models and the laboratory itself was recognized and listed as a genuine museum. Apparently, a small part of this museum has survived as a display case within the Department.

The following delightful poem by an enthusiastic student appeared in the 1986 Mechanical Engineering Yearbook (the name of the student could not be found).

Ode to Jack
Oh, my favorite Lecturer Jack
You overwhelm me with the intelligence I lack
I clamber for seats in the lectures you pack
But can't get enough and must keep coming back.

To hear those mind-boggling lectures, you fill
In seventh year, I'm attending your lectures, still
As you boggle my mind with your mind-boggling skill
Give us all such a mind-boggling thrill.

To the vastness of your mind there is no measure
You know that your presence we truly treasure
Your personal force gives me moments of pleasure
And a couple of times you have given me seizures.

I really don't have halve your wit
If only I understood your wisdom just a bit
I would be good enough for your lectures and fit
To escape groveling in this intellectual cesspit.

We appreciate your mind-boggling factual generosity
The way your lectures progress with such rapid velocity
Yet some villains fall asleep but to this blatant atrocity
You magnificently refrain from any animosity.

Jack also designed and built, over a period of several years, a Universal Display Machine, commonly referred to as "The Thing", see Fig. 4.

The purpose of the machine was to provide a platform for demonstrating the movement and function of different types of mechanisms and such practical mechanical devices as belts, constant velocity joints, bearings, and gears. It was powered by a single electrical motor and all the moving devices were driven through the belts, chains and gears by this single motor. The display machine showed the working mechanism of a sewing machine, the movement of a paint-mixer linkage, a number of different constant velocity joints, (including one from a front-wheel driven car), as well as demonstrating kinematic theory such as the movement between the fixed and moving polodes of a quick-return mechanism. "The Thing" is a singularly attractive

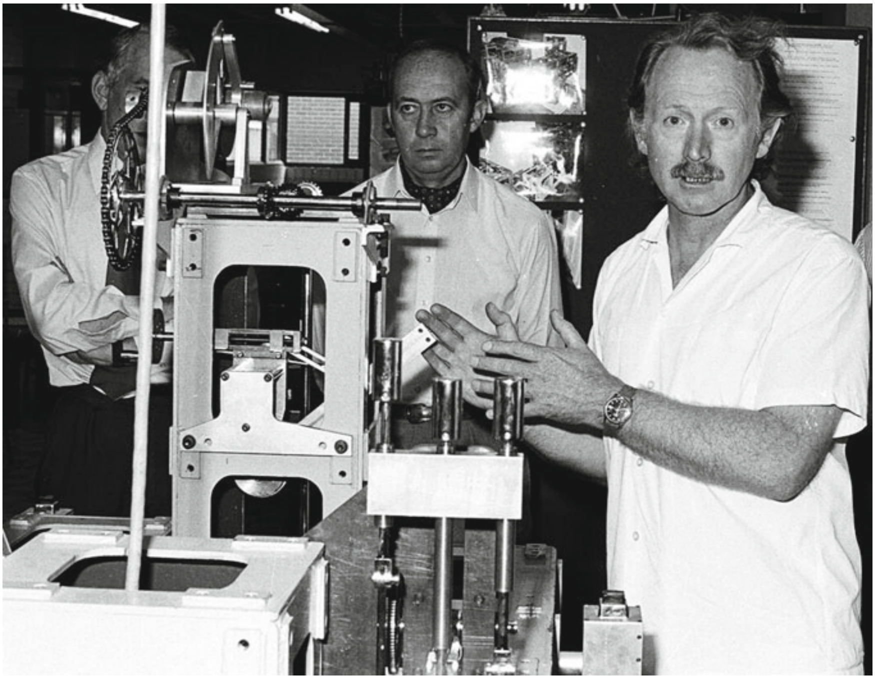

**Fig. 4** Jack explaining the operation of the universal display machine

feature not only to the students and their parents but all of the visitors to the Department showing many machine components moving in an organized and fascinating manner.

During the months of June and July in 1979, Jack organized an international conference/workshop on the theory of machines that was hosted by the Mechanical Engineering Department. Several renowned American academics in the areas of mechanism and machine science attended the workshop. The attendees included Bernard Roth, Stanford University, Kenneth J. Waldron, The Ohio State University, Delbert Tesar, The University of Texas at Austin, Arthur Erdman, University of Minnesota, and John Uicker, University of Wisconsin, Madison. The workshop also included most of the well-known Australian kinematicians of that period, including Ken Hunt, Monash University, Jeremy Hirschhorn, the Institute of Technology, Sydney, J. Eddie Baker, University of New South Wales, John Gal, Sydney University, and Fred Sticher, University of Technology, Sydney. John and Fred were two of Jack's former postgraduate students at Sydney University. Even though Jack had extensive and longstanding relationships with all of these academics, as well as with colleagues from Eastern Europe, this workshop was the first occasion when a kinematics-specific conference and workshop was held in Australia. Figure 5 shows Jack listening to a presentation by Ken Hunt at the international workshop. (As an aside, we could mention that Hirschhorn's book *Kinematics and Dynamics of*

**Fig. 5** Jack (third from the left) at the international conference/workshop

*Plane Mechanisms*, McGraw-Hill Book Company, Inc., New York, 1962, is highly recommended to the reader).

## 2 List of Main Works

A list of Jack's most important publications is presented here, however, it is important to appreciate that this bibliography constitutes only a small part of the contributions of this intellectual giant. A large number of his publications appeared in obscure eastern European conferences and journals, and represent a singular achievement in their own right. The beautifully colored and complicated diagrams that appear in his two volume 500-page Magnum Opus *Freedom in Machinery*, published as a complete work in 2007 by Cambridge University Press, are highly recommended to the reader.

Phillips, J. R., A graphical method for skew forces and couples, *Australian Journal of Applied Science*, Vol. 6, No. 2, pp. 131–150, printed by C.S.I.R.O., Melbourne, 1955.

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Phillips, J. R., The powered vehicular wheel plane-rolling in equilibrium: a consideration of slip and rolling resistance, Proceedings of the First International Conference on the Mechanics of Soil-Vehicle Systems (Primo Convegno Internazionale del Movimento Fuori Strada), Politechnico di Torino, printed by Edizoni Minerva Tecnica, Italy, pp. 541–554, June 1961. Discussions of paper by V. E. Gough, A. R. Reece, and W. F. Buchele, pp. 555–558.

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Phillips, J. R., Determination of instantaneous screw axes in spatial mechanism, *Transactions of the First International Conference of Mechanisms and Machines, IFToMM,* Varna, Bulgaria, Mechanical and Electromechanical Institute, Sofia, Bulgaria, Vol. 1, pp. 245–269, September 27–30, 1965.

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Phillips, J. R., On the question of freedom and constraint in constant-velocity universal couplings, *The Institution of Engineers, Australia, Sydney Division.* This paper is the Preprint prepared for an address that was given at the Institution on August 15, 1968.

Phillips, J. R., Some observations of the solidity of kinematic chains of mobility unity, *Transactions of the Second International Conference on Mechanisms and Machines, IFToMM,* (Additional Papers), Politechnika Warszawska Katedra, Teorii Maazyn Mechanismow, Zakopane, Poland, September 1969.

Phillips, J. R., Geometry of backlash in spatial mechanisms, *Transactions of the Third International Conference on Mechanisms and Machines, IFToMM,* Kupari-Dubrovnik, Jugoslavia, Vol. H, pp. 339–354, Masinski Facultet Universita u Beogradu, September 1971.

Phillips, J. R., Aspects of TMM at the University of Sydney, *Transactions of the First IFToMM International Symposium on* Educational Activity in the Field of Mechanism and Machine Theory, SEMeMAT'75, January 27–30, 1975, Pamporovo, Bulgaria.

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Phillips, J. R., and Zhang, W. X., The screw triangle and the cylindroid, *Proceedings of the Seventh World Congress on the Theory of Machines and Mechanisms, IFToMM,* Seville, Spain, Vol. 1, pp. 179–182, September 1987.

Phillips, J. R., Glimpsing the new, *Proceedings of the Seventh World Congress on the Theory of Machines and Mechanisms, IFToMM,* Seville, Spain, Vol. 1, pp. 5–6, 17–22, September 1987. (A keynote paper addressing the importance of screw theory as applied in the field of freedom and constraint in machinery). The paper was supported by a short piece of silent film (in color) of the *Display Machine* that was designed by Phillips and built by H. Nibbe in the Department of Mechanical Engineering at the University of Sydney.

Phillips, J. R., *Freedom in Machinery, Volume 2: Screw Theory Exemplified*, Cambridge University Press, London, England, 1990. ISBN: 0–521-25,442–6. (Contains 251 pages, illustrated with numerous photographs and figures).

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Phillips, J. R., *Freedom in Machinery,* Volumes 1 and 2 combined, 500 pages, Cambridge University Press, London, England, March 2007. (First paperback edition of the earlier two volumes).

## 3 Review of Main Works/Contributions

In 1984, Jack published his first book *Freedom in Machinery, Volume 1: Introducing Screw Theory*. The book deals with the questions of freedom and constraint in machinery and asks insightful questions, such as, whether the smooth working of a machine will depend entirely upon the accuracy of its construction. As Jack addresses such questions, he explores the geometrical interstices of the so-called screw systems at the joints of the machine. This combines, in three dimensions directly, the twin sciences of kinematics and statics of rigid contacting bodies, striking deeply into the foundations of both. It introduces the idea that the kinetostatics of spatial mechanism (combination of the kinematics of the motions and the statics of the forces between the links in contact) is a valuable discipline, thus setting down for further development the beginnings of screw theory. A special feature of this volume is the profusion throughout of its spectacular perspective line drawings, which excite and assist the imagination. The book is important in the general areas of modern machinery and robots, where an ability to think and to work in three dimensions is vital. Since it is of course not possible to design such systems until the geometrical nature of the practical joints and the spatial movements of the various parts of modern machinery is properly understood, these new areas make this book an important addition to the literature. The book, with its main accent upon geometry, makes its thrust at those levels of our understanding that lie below the algebra and the mere programming of modern computers. Jack's direct personal style makes even the more difficult of his geometrical and other ideas accessible to a wide range of mathematicians, research workers, and mechanical engineers.

In 1990, Jack published his second book, *Freedom in Machinery, Volume 2: Screw Theory Exemplified* (Phillips 1990). The book deals by way of examples with the application of screw theory, not only in the analysis and synthesis of mechanisms, in general, but with the problems in real machine design. Because the focus is three dimensional (and thus not easy to grasp when presented by means of mathematics alone), screw theory needs to be and is presented here with the help of carefully drawn geometrical figures which transport the reader directly into the three-dimensional domain. There are two important aspects to the book. First, it is a fundamental work in the area of the kinetostatics of mechanism and second it is a seminal work of importance for the mechanical design of robots, both the relatively simple robots of today and the much more versatile robots of the future. The book is of interest to final-year undergraduates in mechanical engineering, and to designers and computer scientists in the field of robots and their development. It is also of interest to mathematicians and of value to molecular biologists, entomologists and others interested in the mechanics of biological joints and movements. Jack stated, several years later, that looking back on it, he regretted very little of what he wrote in his two books. Indeed, he saw them as a non-applied philosophical forerunner to his later work.

Two years after Volume 2 was published and some five years after his retirement from regular teaching at the University of Sydney (where teaching normally helps to generate original ideas), Jack had wonderful insight regarding three-dimensional gearing. The insight came from the classical line geometers of the nineteenth century, from Ball of the early twentieth century, and from his own long practical experience with the gist and the practical workings of screw theory. The idea was that spatial gearing (he was referring to the various crossed helical, bevel, worm, and hypoid gears) did not have a fundamental law and was, thereby, devoid of a unifying theory. Jack claimed that the nearest to a fundamental law we can arrive at, with the current theory of spatial gearing, is that, given conjugality (most often with curved line contact), the contact normal at a point of contact must be normal to the plane containing the sliding velocity at that point and that the said plane is of course the common tangent plane to the mating surfaces at that point of contact. Jack was open to the possibility that he may be wrong, but he was convinced that this collection of argument, while not wrong, is however beset with tautology. In planar gearing (and speaking in the reference plane) Jack said with certitude (and correctitude) that, for conjugality, the contact normal must at all times pass through the pitch point. This truth can be found in the classical work of Willis (1838), and the theory of planar gearing rests firmly upon it. Willis clearly explained where, having originated within the meshing, the contact normal must point. His explanation was not in terms of the conditions at the mating surfaces at the point of contact, such as the curvatures, but in terms of the overall architecture of the gear set. Having emerged from the meshing, Willis stated that the contact normal must go to the pitch line.

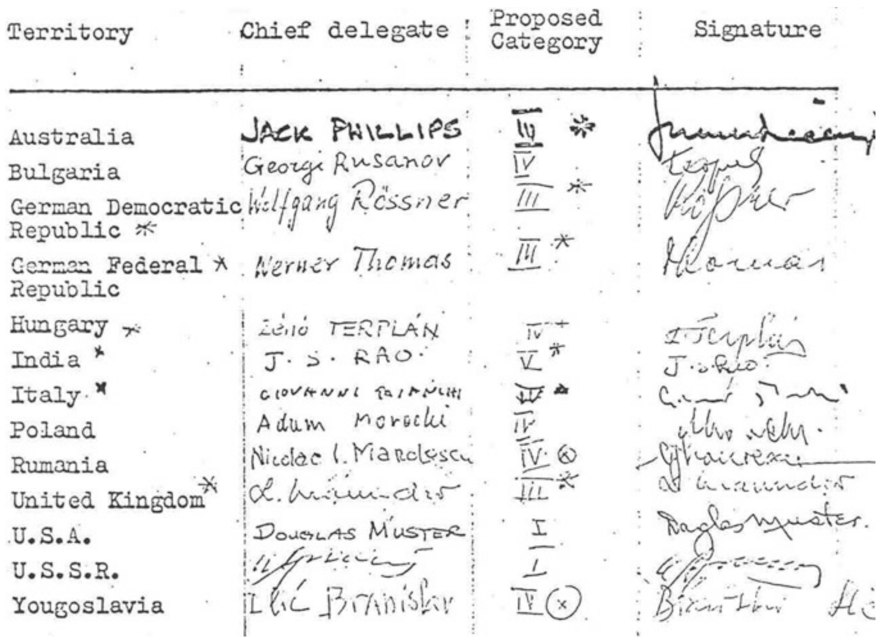
Armed with the work of Ball and a sufficient knowledge of screw theory, to "fly by the seat of his pants", Jack was able to see in spatial gearing that: (a) the unique axis about which either one of the two meshing gears screws with respect to the other is the direct analogue in space of the pitch line; (b) the lines of the linear complex surrounding the pitch line (the pitch of which complex is the pitch of the said pitch line) are the lines that are legitimate contact normals in all of the circumstances; (c) what can be seen as being general spatial involute gearing in the context of all kinds of gearing (bevel, worm, spiroid, hypoid—square and oblique) is inclusive, intelligible, definable, machinable and practical; and (d) in the event that the gears are involute gears, the lines of the linear complex are legitimate lines for selection in design as straight-line-travel paths for the single point of contact. Jack believed this geometrical insight was a significant contribution to spatial gearing and in 1994 he wrote a letter to Terry E. Shoup then Editor of Mechanism and Machine Theory. (Dr. Shoup also served as Vice-President of IFToMM from 1992–1995). Jack's letter summarized his attempt at a fundamental law for spatial gearing and the letter was published in the Mechanism and Machine Theory journal (Phillips 1994).

In 1995, Dooner and Seireg (Dooner and Seireg 1995) published a book on the kinematic geometry of gearing and discussed the importance of the pitch line and the linear complex of lines surrounding the pitch line. Jack claimed that this produces not one fundamental law but, in fact, three fundamental laws; and that none of these laws was the same as the one that he had put forth. Most of their derived gear sets exhibit exact conjugality by virtue of the fact that the teeth of each wheel geometrically generate the teeth of the other, but they do suffer curved line contact and are thereby overconstrained and in that respect unsatisfactory. The spatial involute gear sets, on the other hand, have a mobility of unity and are thereby sufficiently constrained. They are, moreover, machinable by conventional methods, and they enjoy their conjugality unaffected by inaccuracies (both linear and angular) at assembly. This latter property is a function of the involute helicoidal shapes of the teeth. Involute gear sets do rely, however, upon single point contact. Although this is held by many to be catastrophic from the point of view of wear. Jack, however, held the opinion (except in the special cases of the crossed helical gears where in every case it is an undesirable feature) that wedge film lubrication is encouraged by the benign curvatures and the fortuitously directed relative motions at the mesh and that the predicted catastrophic consequences of single point contact are, in fact, a myth. It is one of those paradoxes that the practical application of machinery has often preceded thorough theoretical understanding by many decades. Jack realized that there was no unifying theory for the families of spatial gears that machine designers had relied upon for centuries. He used his familiarity with screw theory to derive elegantly simple unifying principles that describe these gears. He went on to show how this theory predicts the many practical advantages of the ubiquitous involute gear profile. Other theoreticians believed that the single point contact inherent in crossed gears with involute profiles carried with it a catastrophic sensitivity to wear and metal fatigue. Jack disproved these assertions by showing that highly effective wedge film lubrication is encouraged by benign curvature and sliding contact, and helps to keep the metal surfaces from touching. For example, wedge film lubrication lay at the heart of the ship tilt-pad thrust bearing invention in 1905 by A. G. M. Michell, an Australian mechanical engineer. (Michell was the first to show how it was possible to apply film lubrication to flat thrust surfaces and journal bearings, the result was the widely known and universally adopted Michell bearing.)

In 1999, Jack published a paper which contained some geometrical aspects of skew polyangular involute gearing (Phillips 1999). The paper was intended to encompass all that gearing which (a) transmits between shafts that are skew, (b) employs paths for the points of contact (for the driver and the driven gears) that are both straight and located in space remote from the center distance line, and (c) appeals to pure spatial involute geometry, namely the geometry of mating involute helicoids, for its kinematic synthesis and practical mechanical design. Methods to achieve nominated requirements such as center distance, shaft angle, radial offset and tooth ratio naturally become available, and methods for machining the teeth based upon the concept of the phantom rack were shown to be possible. In 2003 Jack published *General spatial involute gearing* a monograph with more than 500 pages which contain approximately 160 computer-drawn figures and 100 references (Phillips 2003). This work addressed problems which had remained open for some 150 years. The theory of planar involute gearing was generalized to the design and machine-cutting of spatial involute gearing. Involute skew helicals, oblique involute hypoids, offset involute worms, bevels and straight spur gears were all explained by the same unifying theory. A fundamental law, not only for involute but for all kinds of gearing, was enunciated and proven. The spatial involute gearing involved in all cases straight-line paths for both points of contact, a constant angular velocity ratio, absence of any built-in trans-mission error, the non-importance of all minor errors at assembly, toleration of the flexing of an elastic gear box, and an ample opportunity to avoid inadequate load bearing and lubrication. The continuous screw motion of an imaginary straight-sided rack generating contemporaneously both flanks of the spatial involute teeth can be readily related to ordinary engineering practice. Jack's monograph may be his most important contribution to the literature of practicability. Hellmuth Stachel published two interesting papers in 2004 related to Jack's research work on three-dimensional gearing (Stachel 2004; Stachel et al. 2004). The first paper *On spatial involute gearing* and the second paper *On Jack Phillips' spatial involute gearing* were essentially an extension of the geometric approach to spatial involute gearing that was developed by Jack. The papers included several new proofs of Jack's fundamental theorems on spatial gear sets.

In 1965, Jack attended the first International Conference on Mechanisms and Machines which was organized and chaired by Professor Mihail S. Konstantinov from Sofia, Bulgaria. A total of 54 papers were presented at the conference which took place from September 27th to 30th at the Marie Curie Memorial Conference Center at the Drouzhba resort near the city of Varna in Bulgaria. The participants came from 17 countries (including England, Australia, Russia, West Germany, East Germany, and other East European countries) although it is interesting to note that there were no participants from the United States of America. The initiative for the conference came from the Scientific and Technical Union in Bulgaria (the Section on Mechanisms and Machines), and the Mechanical Engineering and Electro-technical Institute in Sofia. An intimate circle of outstanding specialists and scientists in the field gathered together and discussed the pressing need for holding international meetings that would be coordinated both as to time and subject matter. The outcome was the establishment of an International Coordinating Committee whose objectives were to plan future international conferences and to study, and possibly prepare the way for, the establishment of an International Federation on Mechanisms and Machines. This conference in 1965 is viewed as the direct forerunner of the International Federation for the Theory of Mechanisms and Machines Congress and is commonly referred to as the First IFToMM Congress. However, IFToMM was not officially founded until 1969 during the Second World Congress on the theory of mechanisms and machines in Poland. The chief delegates, of the thirteen member organizations, at the IFToMM inaugural assembly are listed in Fig. 6 along with the words, "We, the undersigned chief delegates at the Inaugural Assembly of the International Federation for the Theory of Machines and Mechanisms here at Zakopane, Poland, on 27th September, 1969, declare that we have founded the above-mentioned Federation and that we have adopted its Constitution which is attached hereto and decided to the following categories (see Article 8.4 of the Constitution)." Jack would serve diligently on the IFToMM Executive Committee for two consecutive terms from 1971–1974 and from 1975–1979.

The main promoters of the IFToMM World Federation were Ivan I. Artobolevski (USSR) and Erskine F. R. Crossley (USA), whose principal aim was to bypass the obstacles of the existing Cold War in developing international collaboration in mechanism and machine science for the benefit of the world society. IFToMM started as a family of TMM scientists among whom we can identify the founding fathers; namely: Ivan I. Artobolevski (USSR), Erskine F. R. Crossley (USA), Mihail S. Konstantinov (Bulgaria), Werner Thomas (GFR), B. M. Belgaumkar (India), Kenneth H. Hunt (Australia), J. Oderfeld (Poland), Jack R. Phillips (Australia), George Rusanov (Bulgaria), Wolfgang Rössner (GDR), Zènò Terplàn (Hungary), Jammi S. Rao (India), Giovanni Bianchi (Italy), Adam Morecki (Poland), Nicolae I. Manolescu (Rumania), Leonard Maunder (UK), Douglas Muster (USA), and Ilic Branisky (Yugoslavia). There were 13 Member Organizations which signed, or contributed to, the foundation act. It is interesting to note that at the Twelfth World



| Territory | Chief delegate | Proposed Category | Signature |
|---|---|---|---|
| Australia | JACK PHILLIPS | IV * | |
| Bulgaria | Georgi Rusanov | IV | |
| German Democratic Republic * | Wolfgang Rössner | III * | |
| German Federal * Republic | Werner Thomas | III * | |
| Hungary * | Zeno TERPLAN | IV * | |
| India * | J. S. RAO | V * | |
| Italy * | GIOVANNI [illegible] | IV * | |
| Poland | Adam Morecki | IV | |
| Rumania | Nicolae I. Manolescu | IV | |
| United Kingdom * | L. Maunder | III * | |
| U.S.A. | DOUGLAS MUSTER | I | |
| U.S.S.R. | [illegible] | I | |
| Yougoslavia | Ilić Branislav | IV | |

**Fig. 6** Chief delegates at the IFToMM Inaugural Assembly in Zakopane, Poland

Congress in Besancon, France, from June 17th to 21st, 2007, the number of participating countries was 52, and there were 66 participating countries at the Fifteenth World Congress in Krakow, Poland, from June 30th to July 4th, 2019.

There are four Permanent Commissions and fourteen Technical Committees established under the supervision of IFToMM. Each permanent commission and technical committee are composed of a Chairperson, appointed by the Executive Council, and a Secretary and members, nominated by the Chairperson and appointed by the Council. The general goals for the work of the commissions and the committees are aimed at promoting their fields of interest by attracting researchers and practitioners, including young individuals. The four commissions are (i) the Permanent Commission for Communications, Publications and Archiving; (ii) the Permanent Commission for Education; (iii) the Permanent Commission for the History of Mechanism and Machine Science; and (iv) the Permanent Commission for the Standardization of Terminology. The permanent commission for the history of mechanism and machine science was created in 1972 following a proposal by Jack. This commission was established due to the strong support of the first IFToMM President, Ivan I. Artobolevski, and because of Jack's pioneering vision. Jack recognized the importance of the history of the machine and mechanism community and of the discipline it carries out, from a technical-historical point of view. Also, and perhaps above all, to track the developments of the IFToMM Federation and the mechanism and machine science. The commission was established to promote the republishing of classical works of reference and the collection and circulation of material and information in the field of mechanism and machine science; to maintain the Archive of the Federation; and to promote activities and works in the history of mechanism and machine science. Jack argued that knowledge of the discipline's history is essential for building its identity. Between 1972 and the present time there has been nine Chairs of the Permanent Commission for the History of Mechanism and Machine Science. Jack served as the inaugural chair of the commission from 1972 to 1981, then Elisabeth Filemon (Hungary) from 1982–1989, Teun Koetsier (the Netherlands) from 1990–1997, Marco Ceccarelli (Italy) from 1998–2002, Hong-Sen Yan (Taiwan) from 2003–2006, Hanfried Kerle (Germany) from 2007–2010, Thomas Chondros (Greece) from 2011–2013, Olga Egorova (Russia) from 2014–2017, and Alessandro Gasparetto (Italy) from 2018–2023. Teun Koetsier also served as the Vice-Chairman for the IFToMM Archive. Figure 7 is a photograph of the first four Chairs of the Permanent Commission for the History of Mechanism and Machine Science.

In 2000, the First IFToMM International Symposium on the History of Mechanisms and Machines (HMM 2000) was held at the University of Cassino, Italy, May 11–13, 2000. The Symposium was hosted by Marco Ceccarelli, Director of the Laboratory of Robot Mechatronics and Professor in the Department of Industrial Engineering, Tor Vergata University of Rome, Via del Politecnico, Rome, Italy. Marco is also a Past-President of IFToMM, serving from 2008–2011 and from 2016–2019. The primary aims of the symposium were to establish an international forum for presenting and discussing historical developments in the science of mechanisms and machines. The symposium was devoted mainly to technical aspects of the historical developments and was mainly addressed to the IFToMM community. This established

**Fig. 7** From left to right: T. Koetsier, J. R. Phillips, E. Filemon, and M. Ceccarelli

**Fig. 8** Jack on the right side of the back row

a specific congress area for the commission on a regular basis and with an international organization that achieved great success in planning events on all seven continents. Also, the symposium was characterized by a commission with a large number of active members (more than 45 members). Figure 8 shows Jack in attendance at one of the technical sessions of the first international symposium.

Due to the success of the first International HMM symposium, the event has been moved to different cities around the world. Also, the symposium which was initially held once every four years was re-organized to occur once every two years. The Seventh International Symposium on the History of Mechanisms and Machines (HMM 2022): *In Memoriam of past distinguished members* was originally scheduled for 2021, however, due to the Covid-19 pandemic the symposium was postponed until April 28–30, 2022, and held in Granada-Jaen, Spain.

In 2004, Jack attended the IFToMM Eleventh World Congress from April 1st to April 4th, in Tianjin, China. The congress had been postponed from August 18–21, 2003, due to the viral respiratory disease SARS (Severe Acute Respiratory Syndrome). Figure 9 shows Jack in attendance at one of the technical sessions of the congress.

Figure 10 shows Jack attending a meeting of the Permanent Commission for the history of mechanism and machine science during the Eleventh World Congress. The figure also shows Jian S. Dai (United Kingdom) on the front right-hand side and Marco Ceccarelli on the front left-hand side of Jack.


**Fig. 9** Jack on the right side of the front row

**Fig. 10** Jack at the permanent commission meeting in 2004

Jack's contributions to IFToMM were recognized in 1999 when he was elected an honorary member of the federation joining only ten other individuals to be so recognized. An honorary member is a person who has contributed by life time achievements and an outstanding international reputation to the blossoming of mechanism and machine science and the thriving of the Federation. This is the highest distinction bestowed by IFToMM. The total number of honorary members cannot exceed twenty, and the number from any Member Organization must not exceed three. Then in 2004 Jack was further honored with the IFToMM lifetime service award at the

**Fig. 11** Jack, Karl, and Elayne celebrating Jack's lifetime service award

Eleventh World Congress. The award is for a person who has provided substantial voluntary service for the whole Federation, marked by outstanding performance, effective leadership and prolonged and devoted commitment for the international activities of IFToMM. At this time, Jack had served the federation faithfully for a period of more than 35 years. Figure 11 shows Jack with his partner Elayne Russell and the Austrian kinematician, Karl Wolhart, during a reception at the Congress to celebrate his award.

## 4 On the Circulation of Works

On one occasion at a Congress of ANZAAS (that is, the Australian and New Zealand Association for the Advancement of Science, an organization founded in 1888) Jack spoke on the complexities of the kinematics of three-dimensional mechanisms (that is, the assembly and motion of mechanical parts connected by hinged joints and sliding pairs). Figure 12 shows Jack at the congress illustrating the kinematic behavior of an open-chain spatial linkage, and the difficulties associated with predicting the motion. Jack explained how nature had created the most intricate and beautiful spatial mechanisms and revealed his kinematic analysis of the claw of a lobster that is joined to the body by a series of pivot joints. (The posture problem was investigated by a number of kinematicians over many years and became known as the "lobster

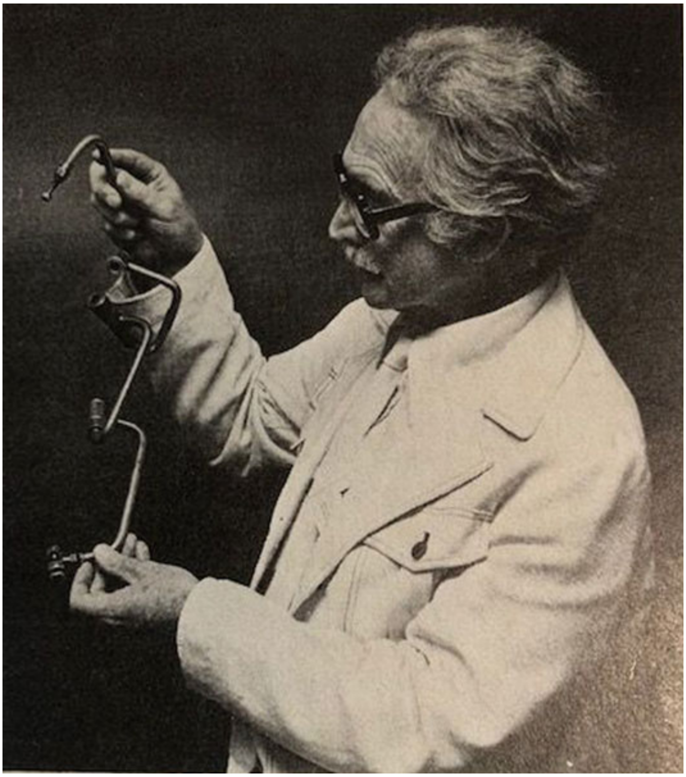


**Fig. 12** Jack illustrating the difficulties associated with the kinematic study of an open-chain spatial linkage

arm problem"). One of Jack's research grants provided for numerous studies on live specimens, measuring the forces exerted by the muscles as the lobster ripped the flesh from its prey. With magical choreography of his arms and wrists, Jack explained how the lobster has optimized its claws to exert the maximum ripping force for minimum muscle effort. He revealed how his research grant provided for sufficient specimens and experiments to enjoy a regular meal of the best lobster that the Sydney restaurants had to offer. Jack enjoyed demonstrating how the human hand and the arm are endowed with extraordinary properties. Holding a blackboard duster in his clenched fist he would show how the arm can only turn the blackboard duster once, perhaps a little more than 360 degrees for people with greater joint flexibility. Picking up an empty glass Jack would show how it could be rotated an infinite number of times, held only by the thumb and forefinger, without at any stage putting the glass down to reposition his grip.

Jack would spend hours with colleagues and friends explaining the kinematics of a wine bottle as he moved it through a series of positions from an initial posture (upright on the table) to a final posture (where the wine flowed freely into his inclined glass). What seemed to be so simple (the family of motions of an axi-symmetric rigid body) turned out to be mathematically so complex and the subject of an endless debate. During most of the fifty-year period from 1953 to 2003, screw theory was the guiding influence for Jack. The theory of screws and screw systems has taken him from the static force analysis of the trailed disc plough to the freedom in machinery and, finally, to the geometry and kinematics of general spatial involute gearing. The cylindroid, along with the various kinds of hyperboloid, with their throats elliptical, circular and parabolic, have been his ubiquitous companions. Jack enjoyed all of this amazing journey. For him it was an unfolding of understanding of the kinetostatics of steady-state machinery. Along with others, of course, he was able to find a better way of consolidating the factors at work in the general question of freedom in machinery; and, in many important ways, Ball was at the root of that. Without Ball, all of this history might not have occurred as it did. As Jack clearly pointed out to me, on more than one occasion, we make our plans and direct our work, but we stand on the shoulders of giants, and we see the future more clearly by virtue of this. I, for one, find it fascinating to see the progressive unfolding of Jack's developing ideas. Jack made significant contributions to the theory of mechanisms and machines. It was fitting that Jack presented the keynote address at the Ball Commemoration, Ba11 2000, July 9–11, 2000, Trinity College, Cambridge University, Cambridge, England. His keynote paper was entitled *From the trailed disc plough with ball to general involute gearing* (the paper is listed in Sect. 2). This conference, organized by the late Joseph Duffy, was a celebratory occasion the likes of which we seldom see today. Over a period of several days, a group of scientists (including the late Kenneth H. Hunt) united in their respect for Ball met to pay homage to him and his work. They brought their contributions to an interim occasion of great significance.

## 5 Legacy and Interpretation of Contributions

Sadly, Jack passed away in Sydney, Australia, on January 11th, 2009. A few months before his death the paper *From the Trailed Disc Plough to Spatial Involute Gearing and Beyond* was published in Mechanism and Machine Theory (Volume 43, Issue 8, pp. 929–933, August 2008) to help celebrate Jack's 85th birthday. Jack was never one to rush an idea into premature publication and at the time of his passing Jack was writing a paper with a tentative title *Discovery as distinct from invention, and the geometry of the actuality in machinery*. Sadly, his ultimate work, *An Atlas of the Screw Systems*, also remains unfinished. Jack claimed that this was to be a somewhat ambitious coffee-table type compendium to be available in eye-catching color and that the work was close to completion. The paper would portray, in three-dimensional perspective, panoramic views of the screw systems at the joints and elsewhere in mechanism. James Trevelyan wrote "Yet, as Jack wrestled with the mathematical complexities of mechanisms made from rigid components, the world of mechanical engineering moved on. Jack's work through the twentieth century, alongside the achievement of other great mechanism scientists, leaves us a guiding legacy from which we can embark on that still greater quest. Jack was a mechanical engineer, an academic, a kinematician, a wine lover, an entertainer, and was one of our most lovable characters."

Jack worked tirelessly at the University of Sydney for 24 years from his recruitment at the beginning of 1963 until his formal retirement in December 1986. At the time of his retirement Jack was an Honorary Research Associate and he claimed that his retirement was one year short of his entitlement to a fine bronze medal and a cup of tea in the quadrangle with the vice-chancellor to recognize 25 years of long service. Jack did, however, receive a reasonable superannuation from his "early" retirement and an ongoing position as an honorary research associate. John Gal, one of Jack's graduate students in the late 1960s, wrote some forty years later; "Jack was a true academic. He always questioned, he always discussed, and he always examined in great detail. His classes in kinematics and the theory of machines were spectacular demonstrations of his understanding of the fundamentals and how to convey this to novices in the area. Without notes or equations, but with a plethora of colored chalk Jack explained with humor and to great effect how the understanding of freedom and constraint in machines is essential for good, practical design. He entertained, but most crucially, he taught as the real teacher he was. As a supervisor he led not only by example and by showing, but, as one of his post-graduate students, Hon Yu, said, by allowing you to discover and explore for yourself. This, together with his expression of confidence in his students' abilities, created a sense of equality and collaboration rather than hierarchy between research student and supervisor. Jack was a great teacher but especially he understood the meaning of real friendship. He will always be remembered as a friend and colleague."

**Acknowledgements** The author is pleased to acknowledge the written communications and photos from John Gal, one of Jacks former graduate students at the University of Sydney. Also, acknowledged is the writing of James Trevelyan, Emeritus Professor in the Engineering School at The University of Western Australia, Perth, and former Discipline Chair for Mechatronics. Finally, the author recognizes the support of Marco Ceccarelli, Professor Department of Industrial Engineering, University of Rome Tor Vergata, Roma, Italy, and Scientific Editor of the Springer Book Series on History of MMS and on Mechanism and Machine Science.

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# Alberto Rovetta (1940–2020)

**Marco Ceccarelli and Chiara Rovetta**

**Abstract** Professor Alberto Rovetta, born in Brescia in 1942, was a second generation IFTOMMist very active in the initiatives of the IFToMM Federation and in the issues referring to MMS in both traditional and innovative aspects. Graduated in Milan in 1966, he was immediately involved in international activities by his mentor Prof. Giovanni Bianchi and made important contributions with pioneering solutions to the development of Robotics in Italy and internationally. In the IFToMM community he devoted a lot of energy in the various levels of leadership and in the various bodies of the IFToMM, even becoming a member of the Executive Council. He also contributed to the design of mechanisms, and he dedicated a particular interest to the History of Mechanics. He was able to transfer intense and extensive research activity to his academic teaching forming new engineers and new researchers. His pioneering solutions and his peculiar dynamism have allowed him to obtain highly prestigious results recognized with national and international awards and prizes, including the Dedicated Service Award of the IFToMM community in 2010.

## 1 Biographical Notes

Alberto Rovetta, Fig. 1, (Rovetta 2021; Ceccarelli and Gasparetto 2020; Kedzior 2010; Ceccarelli 2022), was born in Brescia, Italy, on 19 June 1940, but he was resident in Milan since the time of his studies at the Technical University of Milan (Politecnico di Milano). He passed away in Milan in his house on 25 November 2020.

Prof. Rovetta was married with Anna, who gave him a son Francesco in 1972 and a daughter Chiara in 1973.

M. Ceccarelli (✉)
University of Rome Tor Vergata, Rome, Italy
e-mail: marco.ceccarelli@uniroma2.it

C. Rovetta
Omron Electronics, Milan, Italy



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a) b)

**Fig. 1** Professor Alberto Rovetta (1940–2020): **a** in 2015; **b** student in 1959. *Courtesy* of Rovetta Family

He graduated from the Politecnico di Milano on 14 March 1964 with a degree in Electronic Engineering. Just after he started academic career covering all the positions until to get the position of full professor. In 1980 he was appointed Full Professor of Machine applied Mechanics with teaching activity mainly on Robot Mechanics and on Design of Machine Elements at the Politecnico di Milano. He retired from academic teaching activity in 2015. Since 1991 he was primary devoted to the teaching of Course of "Robot Mechanics" as linked to his research activity and interests in Robotics.

Prof. Rovetta activity was centered on research with important efforts in teaching as motivation and transfer of his interests in investigation of scientific-technical achievements for the development of Technology and welfare of the society.

During his long academic career, he directed the teaching activity to engineering and architecture students at graduate and undergraduate levels within a large variety of topics such as Mechanism Design, Robot Mechanics, Industrial Design, Visual Communication, Foundations and Methods of Industrial Design Modelling and simulation of mechanical systems. In his last teaching period, he gave courses on Design of Intelligent Robots, and Space Robotics with pioneering tele-teaching to student worldwide, Fig. 2. He was invited to give courses abroad with intensive programs, even on a regular basis like the course Space Robotics at Beijing University of Aeronautics and Astronautics.

Prof. Rovetta addressed important attention and efforts also in international collaborations and relationships covering leadership position in projects and initiatives with strong human relationship. Figure 3 is an emblematic example of this his attitude


**Fig. 2** Prof Rovetta giving a lecture on new frontiers for Robotics

combining scientific meetings with social friendly contacts, as per a meeting with prof. Teru Hayashi in Japan together with his wife.

Just to cite the most important positions also for him, the following can be noted in broad fields of activity:

- Chair of the International Committee Uita-Unesco for Advanced Technologies
- Member of the B6/2 Committee of the ITU_UN of United Nations
- President of SINT (International Society of Theoretical Neurobiology) in 1993–1997
- Member of the Technical Committees of IFAC (International Federation for Automatic Control): Committee for Advances in Manufacturing Technology and Committee for Advanced Control
- Member of the International Commission for the General Affairs of the IEEE (Institution of Electric and Electronic Engineers)
- Coordinator of the Polytechnic of Milan of the Pilot Project of European Community ECTS (the 1998–1998) and of Project TEMPUS towards the Countries of the European East (1992–1998)
- Coordinator of Program INFOPOVERTY sponsored by EU, UNESCO, OCCAM, with collaboration from many universities all around the world (2000–2008).

More specifically he worked leader position in research projects, among which he was used to outline:

**Fig. 3** Prof. Rovetta meeting Prof. Teru Hayashi with his wife Anna (second left) and Hayashi's wife

- Member of the Pre-Feasibility Committee for the Finalized CNR (Italian National Council of Research) Project titled: "Application of robotics and telematics in biomedicine and surgery" and of the Committee for the Strategic CNR Project: "Robotics in Surgery".
- Member of the Commission of Feasibility and Prefeasibility of the Finalized Project 'Robotics' of the CNR (Committee and National Research Council), and Member of the Customers for the Finalized Project 'Robotics' of the CNR.
- Responsible of research with grants from the Space Italian Agency (ASI).
- Responsible the Project "Network for Rare Tumors" with the Institute of Tumors, Scientific Center and Hospital, Milan, Italy.
- Principal Investigator of Project "Telesurgery between Europe and USA" with USA in cooperation with NASA and JPL.
- Leader in Robotics Projects in the programs of Italian National Council of Research.
- Principal Investigator of Daphne Project, in European Union, for the neuromotor diseases analysis and with the application of a methodology for the brain control with special devices.
- Responsible of Italy-China Project "Telecontrol and biorobotics" with Jiao Tong Shanghai University in China.

Because of his reputation worldwide he served in several committees for international conferences and as editor or associate editor of international journals. The following conference series are the main ones as linked to his main interests, just to cite few from his large participation over decades of activity: RAAD, Robotics in Alpe-Adria-Danube Region; ROMANSY, Robot and Manipulator CISM-IFToMM Symposium; ICRA, IEEE International Conference on Robotics and Automation; IROS, IEEE International Conference on Intelligent Robots and Systems; and NASA Conference on Telerobotics in Space. He was often invited to give plenary lectures and conference speeches on the frontiers of Robotics. While being member of many societies, like ASME, IEEE, IFAC, SIRI, and IFToMM Italy, prof. Rovetta receive several honors and awards, including membership in Academies, like in the New York Academy of Sciences, Polish Academy of Science, and Accademia of Science and Lettere of Brescia.

In particular within the IFToMM community, (Rovetta 2011; Ceccarelli 2015, 2019), he was continuously involved in planning collaborations and relationships for research and teaching projects, including and intense exchanges of visits also for promoting the IFToMM federation. It is worthful to highlight the following leadership positions also as results of his successful efforts with regular continuous participation and contribution, (Rovetta 2011; Ceccarelli 2014a, b, 2015):

- Member of the Executive Council in the years 1996–2003, Fig. 4
- Chair of IFToMM Italy Member organization in the years 1987–1995
- Chair of the Technical Committee for Micro mechanisms in the years 2002–2005
- Chair of the Technical Committee for Man–Machine Systems in the years 2007–2008.

Beside the above, for several decades and until his last days he was very active member in the Technical Committee for Robotics and Mechatronics and also in the Permanent Commission for History of MMS.

**Fig. 4** Prof. Rovetta (first from the left) at the meeting of the IFToMM executive council in Udine, Italy in 2002

Among the many initiatives, he organized the 9th IFToMM World Conference of Theory of Machines and Mechanisms that was held in Milan in 1995 on 30 August–2 September 1995 with a very successful participation being the IFToMM world Congress with the largest scientific participation over time with 665 papers and 903 registered participants from 56 countries, Figs. 5 and 6 (Rovetta 1995).


a)

PROGRAMME AT A GLANCE

TUESDAY, AUGUST 29, 1995

| Time | |
|---|---|
| 08.30 am | The Conservation and Rehabilitation of the Italian Historical Buildings |
| 02.00 pm | Executive Council Meetings / IFToMM Operative Meetings |
| 06.30 pm | Opening Session and Welcome Reception |

WEDNESDAY, AUGUST 30, 1995

| | Time | Hall I | Hall II | Hall III | Hall IV | Hall V | Hall VI | Hall VII | Hall VIII | Hall IX |
|---|---|---|---|---|---|---|---|---|---|---|
| | 08.30 am-08.50 am | Keynote Lecture | | | | | | | | |
| WA1 | 08.50 am-10.30 am | Mechanisms 1 | Gears-Transmissions 1 | Kinematics 1 | Vibrations 1 | Mechanics Theoretics 1 | Robotics 1 | Modelling in Robotics | Design Methodology | Biomechanics 1 |
| WA2 | 10.50 am-00.30 pm | Mechanisms 2 | Gears-Transmissions 2 | Kinematics 2 | Vibrations 2 | Mechanics Theoretics 2 | Robotics 2 | Measurements in Robotics | Design of Machines 1 | Biomechanics 2 |
| | 00.30 pm-02.00 pm | IFToMM Operative Meetings | | | | | | | | |
| | 02.30 pm-02.50 pm | Keynote Lecture | | | | | | | | |
| WP1 | 02.50 pm-04.30 pm | Mechanisms 3 | Gears-Transmissions 3 | Kinematics 3 | Vibrations 3 | Mechanics Theoretics 3 | Robotics 3 | Manipulators and Robots for Space | Design of Machines 2 | Measurement for Applied Mechanisms |
| WP2 | 04.50 pm-06.30 pm | Mechanisms 4 | Gears-Transmissions 4 | Dynamics 1 | Vibrations 4 | Mechanics Theoretics 4 | Robotics 4 | Robotics in Medical Applications | Safety and Reliability | |

THURSDAY, AUGUST 31, 1995

| | Time | Hall I | Hall II | Hall III | Hall IV | Hall V | Hall VI | Hall VII | Hall VIII | Hall IX |
|---|---|---|---|---|---|---|---|---|---|---|
| | 08.30 am-08.50 am | Keynote Lecture | | | | | | | | |
| TA1 | 08.50 am-10.30 am | Mechanisms 5 | Gears-Transmissions 5 | Dynamics 2 | Rotordynamics 1 | Mechanics Theoretics 5 | Robotics 5 | Biomechanics and Man-Machine Systems | Simulation and Modelling 1 | |
| TA2 | 10.50 am-00.30 pm | Mechanisms 6 | Gears-Transmissions 6 | Dynamics 3 | Rotordynamics 2 | Machines and Systems 1 | Robotics 6 | Man-Machine Systems 1 | Simulation and Modelling 2 | |
| | 00.30 pm-02.00 pm | IFToMM Operative Meetings | | | | | | | | |
| | 02.30 pm-02.50 pm | Keynote Lecture | | | | | | | | |
| TP1 | 02.50 pm-04.30 pm | Mechanisms 7 | Gears-Transmissions 7 | Dynamics 4 | Rotordynamics 3 | Machines and Systems 2 | Robotics 7 | Man-Machine Systems 2 | Simulation and Modelling of Mechanical Systems | |
| | 04.30 pm-04.50 pm | Keynote Lecture | | | | | | | | |
| | 04.50 pm | IFToMM General Assembly | | | | | | | | |

FRIDAY, SEPTEMBER 1, 1995

| | Time | Hall I | Hall II | Hall III | Hall IV | Hall V | Hall VI | Hall VII | Hall VIII | Hall IX |
|---|---|---|---|---|---|---|---|---|---|---|
| | 08.30 am-08.50 am | Keynote Lecture | | | | | | | | |
| FA1 | 08.50 am-10.30 am | Mechanisms 8 | Gears-Transmissions 8 | Dynamics 5 | Rotordynamics 4 | Machines and Systems 3 | Robot Kinematics | Teaching and Educational Trends 1 | Elements "Technological and Industrial Applications" | |
| FA2 | 10.50 am-00.30 pm | Mechanisms 9 | Gears-Transmissions 9 | Control 1 | Rotordynamics 5 | Machines and Systems 4 | Dynamics and Control of Robotics 2 | Teaching and Educational Trends 2 / History | Machine Elements | |
| | 02.30 pm-02.50 pm | Keynote Lecture | | | | | | | | |
| FP1 | 02.50 pm-04.30 pm | Mechanisms 10 | Gears-Transmissions 10 | Control 2 | Vibrations 5 | Machines and Systems 5 | Dynamics and Control of Robotics 1 | Micromechanics 1 | Elements | |
| FP2 | 04.50 pm-06.30 pm | Mechanisms 11 | Gears-Transmissions 11 | Control Simulation and Identification 3 | Vibrations 6 | Machines and Systems 6 | Dynamics and Control of Robotics 3 | Micromechanics 2 | Mechatronics | |

SATURDAY, SEPTEMBER 2, 1995

| | Time | Hall I | Hall II | Hall III | Hall IV | Hall V | Hall VI | Hall VII | Hall VIII | Hall IX |
|---|---|---|---|---|---|---|---|---|---|---|
| | 08.30 am-08.50 am | Keynote Lecture | | | | | | | | |
| SA1 | 08.50 am-10.30 am | Cams Design 1 | Gears-Transmissions 12 | Mechanics Theoretics 6 | Multibody Theory | Structural Analysis | Man-Machine Systems 1 | Production of Systems 1 | Measurements 1 | |
| SA2 | 10.50 am-00.30 pm | Cams Design 2 | Cams Design 3 | Mechanics Theoretics 7 | Robot Kinematics | Man-Machine Systems 3 | Man-Machine Systems 2 | FMS - Automation Systems 2 | Measurements 2 | |
| | 00.50 pm-01.10 pm | Keynote Lecture | | | | | | | | |
| | 01.10 pm | Closing Remarks | | | | | | | | |

b)

**Fig. 5** The 9th IFToMM world congress organized by prof. Rovetta (1995): **a** cover page of the proceedings in four volumes; **b** a table of the general program

a)

b)

c)

d)

**Fig. 6** The 9th IFToMM world congress organized by prof. Rovetta: **a** registration desk; **b** a test of telesurgery during a session; **c** with prof. Pust at the opening; **d** an online interview for the Italian TV network

**Fig. 7** IFToMM President prof. Ceccarelli gives the IFToMM award diploma to prof. Rovetta with his wife Anna in June 2010

His distinguished figure has been recognized in IFToMM with IFToMM Award of Merit in 2010., Fig. 7 (Kedzior 2010).

Prof. Rovetta carried out an intense research activity linked and motivating the teaching of the above subjects with a significant literature production with more than 400 papers in Italian and International journals. From those experiences he also published more than 20 books either with research results or for teaching purposes.

Prof. Alberto Rovetta has been a prestigious figure, who has been admired and taken as inspiration, also for his unique attitude to combine friendships and rigorous scientific activity in working out the true spirit of IFToMM for collaboration, sharing, and improving the technology for the benefit of the society in the welfare of human beings.

## 2 List of Main Works

The huge literature production of Prof Rovetta can be divided in books and papers.

He published the following books, as most of them in Italian as directed to the teaching and dissemination in the Italian communities, Figs. 8 and 9:

A. Rovetta, Exercise of Theory of Mechanisms, Istituto. di Meccanica, Politecnico di Milano, Milan, 1972 (in Italian).
A. Rovetta and E. Turci, Robots without myths, Publisher Clup, Milan, 1987 (in Italian).
A. Rovetta, Robotics, Publisher Hoepli, Turin, 1990 (2nd Ed 2005) (in Italian).
A. Rovetta, Elements of mechanical systems, Publisher Clup, Milan, 1984 (in Italian).

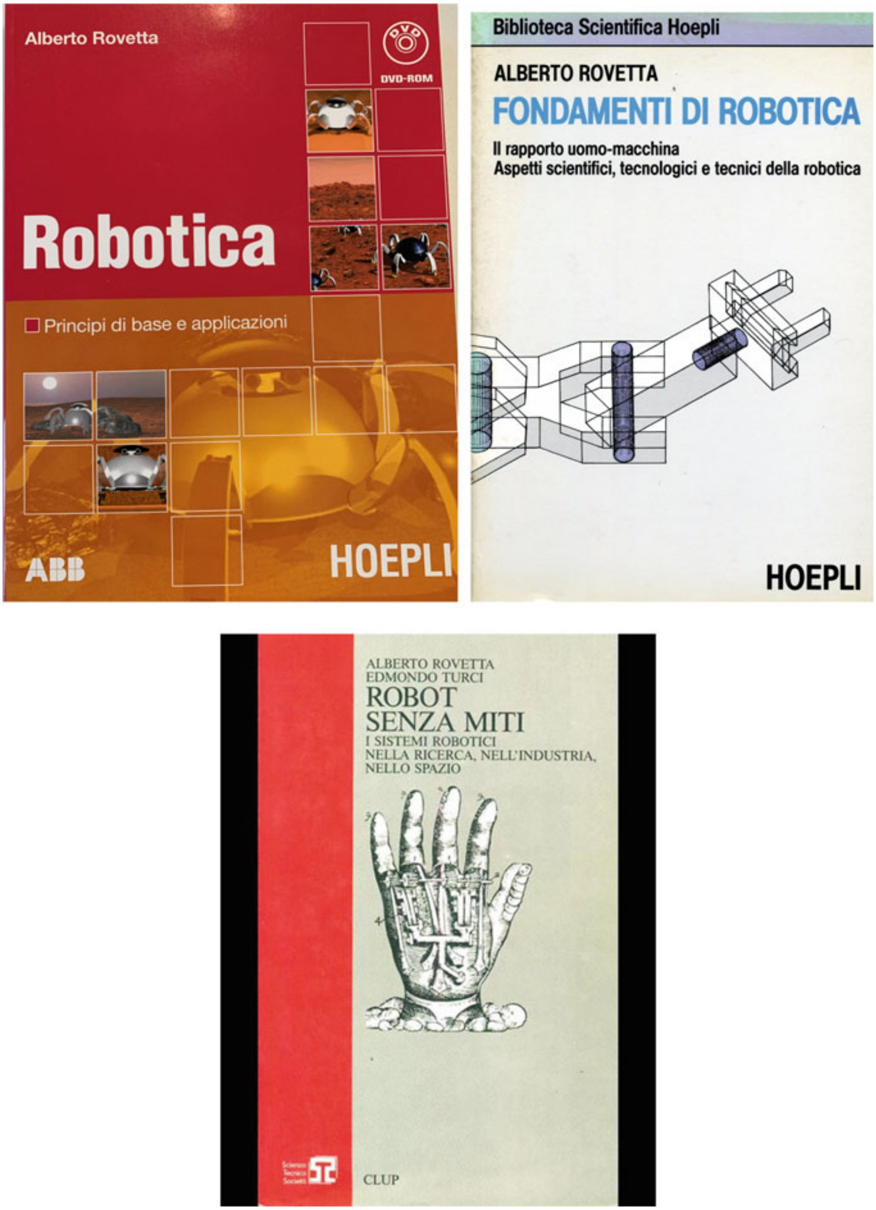


**Fig. 8** Books published by prof. Rovetta on Robotics

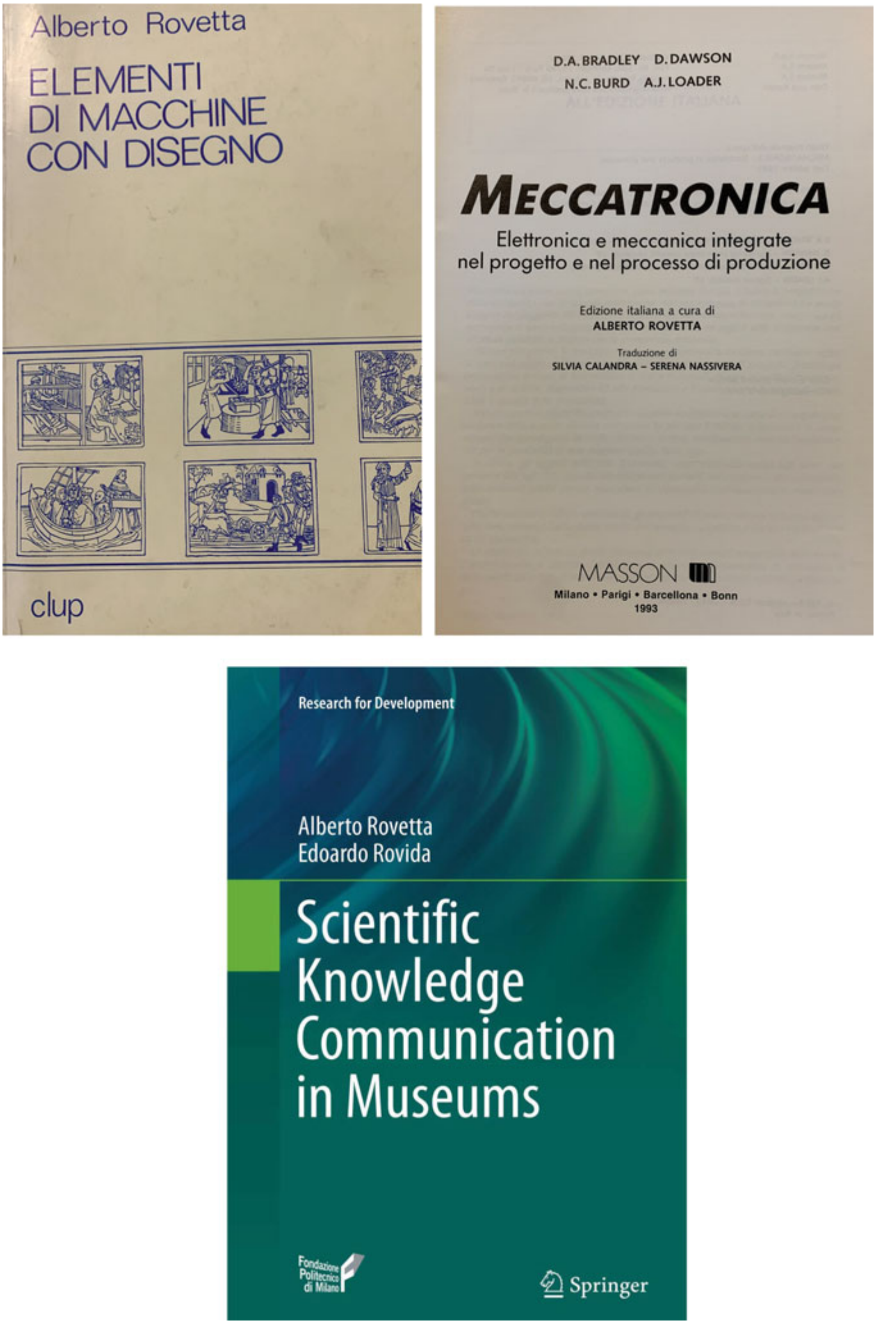


**Fig. 9** Books published by prof. Rovetta on machine design, mechatronics, and museum valorization of machines

A. Rovetta, Fundamentals on Machine Design with Drawings, Publisher Clup, Milan, 1997 (in Italian).

A. Rovetta, robot@internet, Ed. Esculapio, Milan, 2000 (in Italian).

A. Rovetta, Methods of Design, Publisher Clup, Milan, 1994 (in Italian).

A. Rovetta, Communication and design, Publisher Clup, Milan, 1994 (in Italian).

A. Rovetta, Mechanics with CDs, CUSL, Milan, 1995.

A. Rovetta, Design e multimedialità, Ed. Cusl.

A. Rovetta, Robotics, In Manuale dell'Ingegnere -Nuovo Colombo, Vol. II, Item "Robotica", Cap. 12, pag.F527-F596, 84a Edizione, Ed. Hoepli, Turin, 2003.

A. Rovetta, Design methodologies for a colony of autonomous space robot explorers, in: Intelligent robots for Space, NASA-JPL, Ed. Tunstel, 2006.

Other significant subject than Robotics and Mechatronics have included interests on valorization of the history and heritage of the history of mechanical engineering with the book in Fig. 9,

– Rovetta A. and Rovida E., Scientific Knowledge Communication in Museums. Springer, Cham, 2018.

The activity of prof Rovetta gave significant results that were published in national and international journals as well as he was used to present personally in national and international conference, main topics of his main contributions refer to:

- Mechanism Design, with new design of mechanisms and procedure for performance analysis
- Robotics, with new designs of robots and robotic systems
- Mechatronics, with new solutions and integration of systems of different nature
- Service Devices, with solutions in Industry and in service applications, such as medicine fields, communications, and astronautics.

Emblematic examples of Professor Rovetta's significant contributions in robotic solutions can be considered the pioneering designs of the hand of Rovetta-Bianchi, Fig. 10, and of the robot Gilberto, Fig. 11 referring respectively to the publications (Bianchi and Rovetta 1978; Rovetta 1979, 1981, 1985) and (Rovetta 1977).

The Rovetta-Bianchi hand, developed in the end of the 1970s, (Bianchi and Rovetta 1978; Rovetta 1979), is one of the first examples, if not the first one of a robotic hand for grasping by multiple contacts that was developed considering mainly mechanical characteristics linked to the functionality of mechanisms actuated by cables.

The Gilberto robot, conceived and designed personally by Professor Rovetta at the end of the 1970s, (Rovetta 1977), with a mechanical architecture that was open to multidisciplinary integrations since its first realization, is one of the first industrial robots with a laboratory prototype used both in research and in teaching, having been used by Professor Rovetta in the following decades in collaborations in research projects and educational experience activities of students and young researchers.

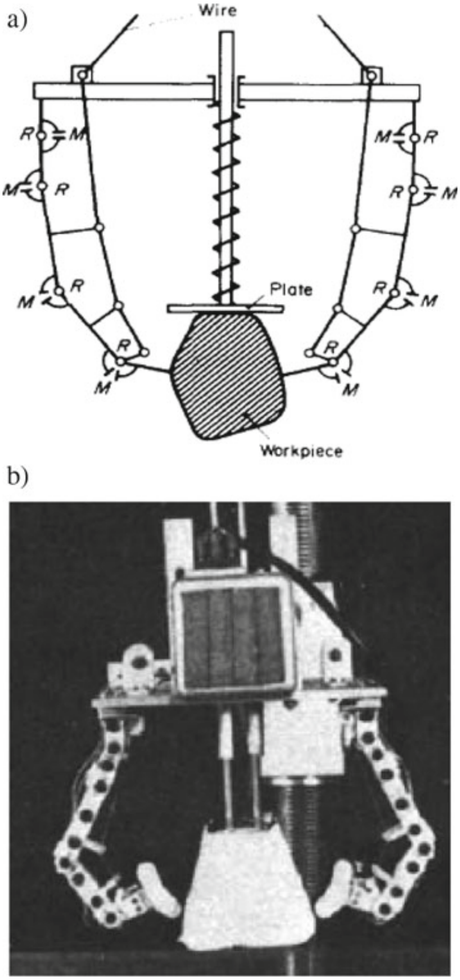


**Fig. 10** The Rovetta-Bianchi hand, (Bianchi and Rovetta 1978; Rovetta 1979, 1981, 1985): **a** a model for research and design purposes; **b** a prototype

Other works of significant interest can be considered the results of Professor Rovetta's attention to the history of mechanical machinery, among which an emblematic example is the one that refers to the study of the chariot of the Egyptian Pharaoh Tut Anck Amun in publication (Rovetta et al. 2000).

A complete long list of the publications of prof Alberto Rovetta can be found in Google scholar with more than two thousands of items, (Rovetta 2022).

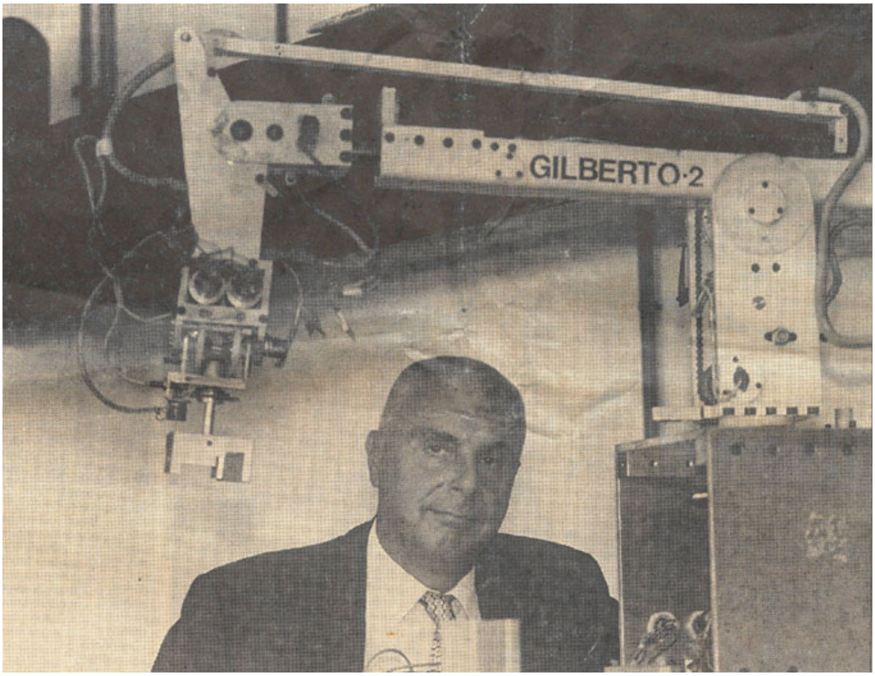


**Fig. 11** The 1977 protype of Gilberto robot, (Rovetta 1977), with professor Rovetta in a newspaper interview in 1980s

## 3 Review of Main Works and Contributions

Prof. Rovetta worked out activity in several topics, even within multidisciplinary teams in national and international research centers, such as in the list he was used to indicate:

Dynamics of mechanical systems.
Dynamics of rotating motors and Cable dynamics.
CAD/CAM applications for systems development.
Machine vibrations.
Rheology of sandy and granular materials.
Design of plastic sliding measurement systems.
Robot hands and Kinematics and Dynamics of robots.
Experts systems for component assembly.
Redundant robots and Voice control for robots.
Dynamic Integration of robot control and vision.
Functional analysis of biomechanical processes.
Application of automatic systems in the manufacturing industry.
Space robots and Telerobotics in space.
Design of extremely light innovative presses.

Robot for the construction of artificial bone in biomaterials.
Neurobiology and Robotics.
Virtual reality in telerobotics.
Medical Robots and Surgical Robotics.
Multimedia systems for the health and the telehealth.
Multifunctional teaching.
Bionic prosthesis with new sensors.
Service Systems for food industry.
Systems of industrial automation.
Nanotechnologies in lower limb prosthesis.
Didactic museum in multimedia shape.
History of past machines and mechanisms.
Robots for planetary exploration in the extraterrestrial grounds.
Robots for grasping recovery of orbiting objects.

From his scientific research activity, he was used to highlight also achievements in terms of design of solutions and new systems, such as
1973: design of an elastic innovative system for telephone (with Prof. Emilio Massa).
1974: design of a vibrating system for sand transportation.
1976: design of a rotary engine.
1977: multifunctional robotic hand (among the first ones in the world).
1982: Gilberto robot with vocal control and vision with microprocessor (one of the first in the world).
1984: first mechatronic lower limb prosthesis.
1986: new industrial system for the production of ice creams and foods.
1992: telerobotics via telephone line (the first of its kind in the world).
1993: first transatlantic surgical telerobotics experiment conducted with JPL on a dummy (on 7 July, first test in the world).
1994: Friend robot for space recovery in collaboration with the Italian Space Agency.
1995: robotic and telerobotic surgical operation on a human patient in collaboration with the Policlinico di Milano.
1996: Michelangelo dummy with microrobotics for heart surgery simulation.
1996: creation of Telehealth in Africa in collaboration with ITU, UN.
1996: instantaneous design of an engine with Alfa Romeo Race Team.
1997: telecontrol of a robotic hand, a robot, a small car from Monterey (Mexico) to Milan.
1999: a space robot for Italian Agency Space (ASI).
2000: telecontrol of a bionic prosthesis in phase of set up.
2001: system of logical recording in Internet of keywords (key-magic).
1999: Daphne Device for analysis of health and neuromotor efficiency.
2000: telecontrol of bionic leg.
2000: Dynamics analysis of chariots of Aegypt Pharaon Tut Anck Amun of 1337 B.C
2001: Logic storage of web sites (key-magic).
2002: Ladyfly system.

2003: European PSYCAR design.
2004: DeeDee system.
2005: NOROS system.
2006: Cirano system.
2007: Cleanwings system.
2008: Wastenergy system.

Many of those results were also object of intellectual property protection by means patent release, such as:

- lower limb prosthesis
- mechanical hand for robots (in conjunction with Alfa Romeo)
- multi-use robot (with Alfa Romeo)
- honing machine for printing cylinders
- gamma ray recognition system
- rotary engine of the trochoidal type
- robotic dummy for heart surgery,
- sensor for prosthesis of lower limb
- system Daphne and Vrepar for the neuromotor analysis for Parkinson disease (with ST Microelectronics)
- robot with voice control
- robot Gilberto for vocal and visual control
- intelligent system of refuses collection
- DeeDee system for analysis of the control neuromotor
- intelligent system for the sensorization of containers for the disposal refuses
- system of taking robotics and maintenance for nuclear reactor
- prosthesis of inferior limb with intelligent control.

One of the most significant contributions of prof. Rovetta, both for pioneering aspects and valuable design results, can be considered the development of the Rovetta-Bianchi hand, (Bianchi and Rovetta 1978; Rovetta 1979, 1981, 1985). The human grip was first studied to find out why human fingers are five, and how there are used in grasping. This motivated the design of a multi-scope hand, like the human one, with original innovative solutions as in the schemes in Figs. 10 and 12. The hand was designed to operate with objects of different shape, with the principle of self-adaptation of the grasping configuration.

The Rovetta-Bianchi hand design was presented with a mechanical hand prototype, which tries to reproduce elements of the functionality of a human hand in grasping, even of high complexity and wide efficiency, as required in robot extremities. Its peculiarities can be summarized in the following aspects.

Multiple Contact Points ensuring in bidimensional cases a stable contact between grasping system and an object if multiple contact points give directions of forces actions are concurrent. In the tridimensional case the contact is stable when there are five contact points, without a convergence of the pressure force action lines. In the human hand, such conditions are performed by two fingers and the palm of the hand itself in the bidimensional case and by the five fingers in the spatial case. The mechanical hand was designed with elastic elements ensuring that the fingers present

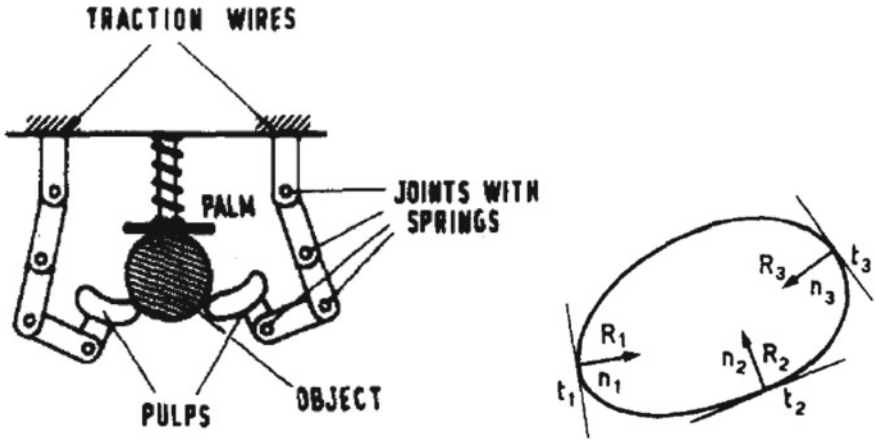


**Fig. 12** Schemes for a robotic hand with multiple contact grasp by Bianchi and Rovetta (1978), Rovetta (1979, 1981, 1985)

subsequent positions with a bending towards the center of the hand, while the palm lifts with an increase of elastic energy of the system, due to the spring inserted in the fingers joints and behind the palm. A biomechanical analysis of the kinematics of the human hand indicated that the motion of phalanges depends on the actuation of the tendons system and is strictly connected with the phalanges morphology. Thus, mechanical solution was realized with three phalanges moved by a traction wire, which acts on the extreme phalanx, and with a system of springs, inserted in the joints of the phalanges. The center of gravity position of the grasped object is determinant to ensure a good relative position between object and hand giving a condition of acceptable grasping. The mechanical palm represented a fundamental element for the stabilization of the grasping action.

Gilberto robot, after its mechanical constructions in 1977, was the first voice-controlled robot, built as early as 1982 in collaboration with Alfa Romeo company as intended for factory work. This stared a great interest of prof Rovetta in synergy of mechanical structures of robots with communications and tele communications, up to attempt successfully an application of telerobotic surgery with transatlantic remote control of surgical machines, for the first experiment in the world in 1993 in collaboration with Prof. G. Bekey of University of South California, (Rovetta et al. 1993).

One other challenging topic that prof. Rovetta attached from his attention to the society welfare was the handling of waste by using and extending approaches of robotic manipulation and tele-communication experiences with mechanical systems, as in several developments that are developed in several publications like the exemplary one (Rovetta et al. 2009).

The investigation on dynamics and functionality of the chariots of the Egyptian Pharaoh Tut Anck Amun used in 1337 B.C. as discovered in his tomb in the Valley of Kings in 1922 was the source of a multidisciplinary collaboration that found out that those chariots seem to be the first mechanical systems involving the use of kinematics, dynamics and lubrication principles. These chariots are displayed at the Egyptian Museum in Cairo a direct experience with the coauthor of the paper (Rovetta et al. 2000) gave the possibility to understand the peculiarities with modern-like characteristics of the main elements, such as wheel rim shape (similar to tyres, with high flexibility), wheel spokes (high flexibility with good resistance),wheel sleeve bearings (low friction, excellent durability), friction and energy consumption between the wheel and axle in motion (reduced friction),overall chariot design (dynamic stability and maneuverability).

Significant is also the attention to recent history of mechanical engineering, even in recognizing figures of the IFToMM community like in the work (Rovetta and Ceccarelli 2020) where he tributed a well-deserved memory to his mentor prof. Giovanni Bianchi with his own identification of belonging not only to his formation but even having contributed to the IFToMM growth.

## 4 Legacy and Today Interpretation of Contributions

The legacy that we can consider left by Professor Rovetta can be summarized in two aspects, namely results in technical-scientific fields and social activity in collaboration and aggregation in national and international contexts.

In technical-scientific terms, the pioneering activities of Professor Rovetta leave results of undoubted historical value in the development of Robotics with research approaches and solutions still of reference today. In particular, noteworthy are the pioneering contributions of Professor Rovetta in the analysis and design of the mechanics of the artificial robotic grasp with multiple contacts with the so-called Rovetta-Bianchi hand, Fig. 10, and in the development of the Gilberto robot, Fig. 11, with a control progressively developed for a multisensory interaction with users.

In the development of the Rovetta-Bianchi hand, an approach of today reference can be recognized with a preliminary experimentation activity on the human anatomy and then performing a computational numerical analysis which, in the case of the Rovetta-Bianchi hand, has allowed to identify the innovative solutions of the fingers with multiple phalanges for an enveloping grasp with actuation, control, and sensors with minimal complexity. The cultural heritage consists precisely in the approach based fundamentally on the science of mechanisms and on the mechanics of grasp as an extension of the mechanics of mechanisms, thus giving a concrete and emblematic example of how the knowledge of the theory of mechanisms can be a valid tool and support for the development of innovative solutions in the field of Robotics. From a historical point of view, both the design and the prototyping of the Rovetta-Bianchi hand are obviously a technical-scientific cultural heritage, which with its prototype still remains a significant reference for the development of multiple contact grasping systems.

The development of the Gilberto robot, Fig. 11, on the other hand, is a clear example of creativity in the design of innovative solutions that were the basis for further innovative developments. The Gilberto robots developed by Professor Rovetta in the period of greatest ferment of the scientific community at the end of the 1970s in developing robotic structures of practical implementation, is characterized by an efficient structure for operation in the field of robotic manipulation that not only had an immediate interest and confirmation also in application solutions in industrial fields but in the following three decades it was the bench of experimentation and development of further innovation especially in the management of the robot. It can therefore be considered an example of cultural value of how a mechanical structure, despite its age, can be the object and source of research and inspiration for innovation considering indeed that in the following thirty years starting from mechanical design, Professor Rovetta, also with various international collaborations, has dedicated himself to improving the performance of the robot, especially in the areas of multidisciplinary and interactive control with a proper human–machine interaction with potential users. This aspect also indicates how efficient can be the integration of mechanical knowledge and the theory of machines and mechanisms with the disciplines now typical of today's mechatronics with a balanced synergy without overestimating or underestimating components of other disciplines so that it is fundamental to obtaining the result not only in design but mainly in functionality of a true mechatronic robotic system. Furthermore, Professor Rovetta in his research and design of robotic systems has always been attentive and motivated to the creation of systems that can be of help and service to human users by practicing the mission that an engineer must pursue in trying to improve not only the technology but above all the quality of life of the users who will use this technology.

In addition to the two cited pioneering examples of Rovetta's activity at the beginning of his career and at the dawn of robotics, we must not forget the already mentioned designs of biomedical systems and prostheses as well as the transfer of robotic solutions to other fields of application such as the example emblematic towards the end of his career related to a hexapod robot for space exploration, as reported for example in Ding et al. (2006).

In conclusion, the legacy of Professor Rovetta from a technical-scientific point of view is the prolific creativity of innovative designs and solutions of robotic systems with an extension capacity that was open also for multidisciplinary integrations.

From the point of view of social engineering activity, Professor Rovetta has demonstrated during his career a characterizing and engaging passion in facing technical-scientific challenges with an empathic approach that has allowed him successful national and international collaborations both at a technical-scientific frames and on a personal social level. This is an aspect that Professor Rovetta often emphasized by saying that the engineer must have passion in his activities, thinking that they are useful to others and in this purpose to recognize the possibility of involving technicians and people who can not only get satisfaction but also can give an effective contribution to the development of those solutions. In this approach we recognize the founding spirit of the IFToMM Federation of which Professor Rovetta can be considered an emblematic example of an IFToMMist having combined technical-scientific activity and a social approach of aggregation and collaboration as well as in the intentions of the founding fathers of IFToMM to overcome barriers of every type to allow technology and in particular that of machines to help the development and improvement of human society. The results of this collaborative and unifying spirit of Professor Rovetta can be recognized not only in his worldwide reputation due to his collaborations and results with significant impact, but above all in the fact that by contributing to the aggregation in collaboration of technical-scientific activities he was also capable of establishing lasting friendship and sharing relationships throughout his professional life, by even managing to attract attention in areas that are not strictly technical and academic. This empathic attitude has also allowed Professor Rovetta to range in different fields even reaching leadership positions in an attempt to develop skills in these specific fields, as for example in the case of his chairmanship of the IFToMM Technical Committee for micro-machines that he was able to manage despite not having a specific activity in the reference topics.

The figure of Professor Rovetta with his versatility in teaching and research activities as well as technology transfer combined with an enthusiasm in international collaboration, especially in the wide range of IFToMM fields, is certainly to be considered a reference figure for the new generations as an exemplary IFToMMist of great value.

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# The Founding Fathers of IFToMM

**Marco Ceccarelli**

**Abstract** This paper presents a short account of the History of IFToMM, the International Federation for the Promotion of Mechanism and Machine Science, focusing on the foundation event and founding fathers. All the founding fathers are listed as signatories and attendees of the Second World Congress on the TMM in 1969 during which IFToMM was founded. In order to honor them short biographical notes of the founding fathers are included referring to their main technical-scientific contributions and their service in IFToMM.

## 1 Introduction

The historical memory of events and personalities of a community represents the identity of the community and therefore the analysis of its evolution as well as its founding principles are an integral part of the community's identity and activities as indicated in the areas of the History of Science and Technology, Koetsier (2000a), with special reference to the IFToMM as in the note (Ceccarelli 2015).

In particular, the history of the IFToMM is partially reported in specific publications of historical memory and in any case documented by the archival documents in terms of reports and the results of activities that can be consulted at the IFToMM archive at CISM in Udine, Italy. A first unitary reference of historical analysis and reportage with an intention of panoramic vision is reported in the first chapter, Angeles et al. (2004), of the proceedings of the HMM 2000 symposium on the History of Machines and Mechanisms with contributions by the past presidents of that moment coordinated by the organizer of the symposium within the institutional tasks of the IFToMM Permanent Commission of History of MMS. Other attempts to delineate the history of the IFToMM have been proposed mainly by past presidents in previous sporadic publications such as those reported in Crossley (1991), Koetsier (2000b), Maunder (1980, 1988), Morecki (1995, 1999), Ceccarelli et al.

M. Ceccarelli (✉)
University of Rome Tor Vergata, Rome, Italy
e-mail: marco.ceccarelli@uniroma2.it

 
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(2020), Ceccarelli (2014, 2016), Ceccarelli (2020a, b). A recent attempt to outline the historical evolution of the IFToMM community is reported by the author in the paper (Ceccarelli et al. 2019), also used for the celebration of the fiftieth anniversary of IFToMM.

In this Chapter, the intention is to summarize the historical memory of the founding event of the IFToMM with particular attention to the memory of the personalities who contributed to the preparation and start of the IFToMM activities. Therefore, the chapter reports short biographical information and technical-scientific profiles of those who are considered the founding fathers of the IFToMM as signatories of the foundation act but also information on those who have contributed in the preparatory activities and also with their presence at the Congress where IFToMM was founded.

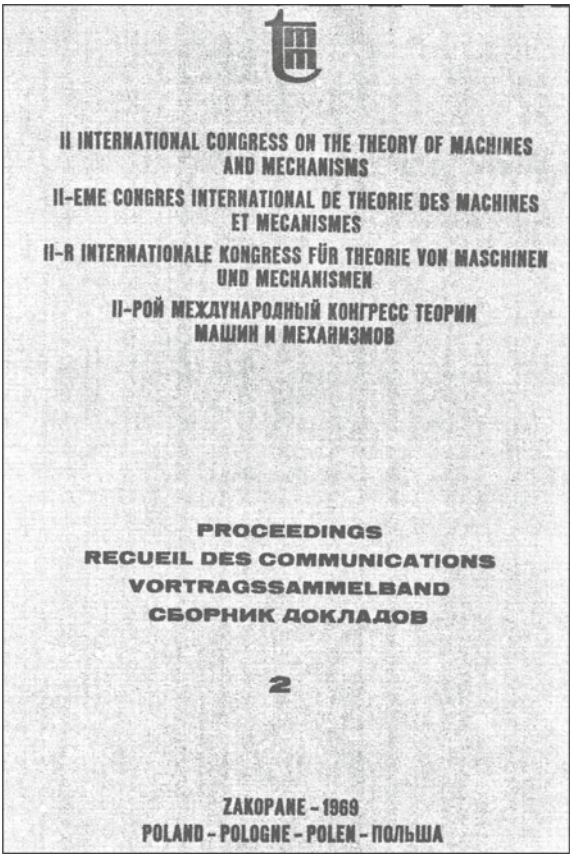
## 2 Foundation and Early Days of IFToMM

IFToMM was founded as the International Federation for the Theory of Machines and Mechanism (TMM, today renamed as MMS) in a meeting in Zakopane, Poland on September 27, 1969, during the last day of Second World Congress on TMM, Fig. 1, Oledzi (1969), Chair of TMM (1969), Smith (1969).

The congress was held from 23 to 27 September 1969 with more than 100 participants (professors with their pupils, collaborators and young researchers) coming from 15 countries from all around the world, Chair of TMM (1969). 66 papers were presented and included in the Proceedings on Automation, Vibrations, Mechanism Dynamics, Machine Dynamics, Rotordynamics, Biomechanics, Optima Design of Mechanisms, Analysis and Synthesis of mechanisms, Prototypes, Experimental Testing, and 5 more papers were only presented since receive with late submission, (Smith 1969).

The Constitutional meeting was held on 27 September 1969 according to a previously agreed Agenda with delegations of several countries from which 13 signed the foundation act, Fig. 2a). The Agenda of the Inaugural Session of IFToMM, Fig. 2b), was a result of along preparation started since the early days of 1960s, mainly in United States and Russia with the main supporting activity from Bulgaria, Poland and UK.

The main promoters of the IFToMM World Federation were Academician Ivan Ivanovich Artobolevski (USSR) and Prof. Erskine F.R. Crossley (USA) with the help of prof Michael Spirov Konstantinov (Bulgaria) and prof Jan Oderfeld (Poland). Their original aim was to overpass the obstacles of the time of the Cold War in developing international collaboration in TMM disciplines for the benefit of the world society, including peace promotion. IFToMM started as a family of TMM scientists among whom we may identify the IFToMM founding fathers, who signed (Table 1) or contributed to the foundation act with the initial 13 Member Organizations, Figs. 3, 4 and 5: Academician Ivan I. Artobolevski (1905–1977) (USSR), Prof. Erskine F.R. Crossley (1915–2017) (USA), Prof. Michael S. Konstantinov (1921–1991) (Bulgaria), Dr. Werner Thomas (GFR) (unknown-unknown), Prof. B.M. Belgaumkar



II INTERNATIONAL CONGRESS ON THE THEORY OF MACHINES AND MECHANISMS
II-EME CONGRES INTERNATIONAL DE THEORIE DES MACHINES ET MECANISMES
II-R INTERNATIONALE KONGRESS FÜR THEORIE VON MASCHINEN UND MECHANISMEN
II-РОЙ МЕЖДУНАРОДНЫЙ КОНГРЕСС ТЕОРИИ МАШИН И МЕХАНИЗМОВ

PROCEEDINGS
RECUEIL DES COMMUNICATIONS
VORTRAGSSAMMELBAND
СБОРНИК ДОКЛАДОВ

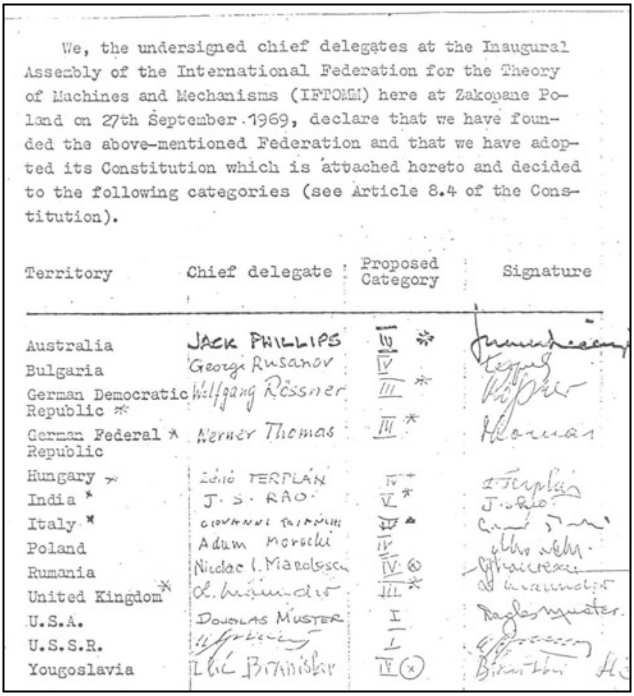
2

ZAKOPANE - 1969
POLAND - POLOGNE - POLEN - ПОЛЬША

**Fig. 1** The front page of Proceedings of the Second World Congress on TMM, Oledzi (1969)

(India) ( 1909–1989), Prof. Kenneth H. Hunt (1920–2002) (Australia), Prof. Jan Oderfeld (1908–2010) (Poland), Prof. Jack Phillips (1923–2008) (Australia), Prof. George Rusanov (Bulgaria) (unknown-unknown), Prof. Wolfgang Rössner (GDR) (1914–unknown), Prof. Walther Meyer zur Capellen (Germany) (1902–1985), Prof. Zènò Terplàn (Hungary) (1921–2012), Prof. Jammi S. Rao (1939–2020) (India), Prof. Giovanni Bianchi (1924–2003) (Italy), Prof. Adam Morecki (1929–2001) (Poland), Prof. Nicolae I. Manolescu (1907–1993) (Romania), Prof. Leonard Maunder (1923-2019) (UK), Prof. Douglas Muster (USA) (unknown-unknown), Prof. Ilic Branisky (Yugoslavia) (1907–1982).

The foundation of IFToMM was the result of an intense activity for stimulating and promoting international collaboration, more than what had been done previously, and the process started in the late 1950s, as documented by several letters that are stored in the personal memories archives of founders and partially in the IFToMM Archive at CISM in Udine, Italy, like the one in 30 May 1969, Oderfeld (1969), in which prof Oderfeld wrote to dr Walsh a summary of the preparatory conditions and a summary of the preparatory events that make ready the foundation of IFToMM in



We, the undersigned chief delegates at the Inaugural Assembly of the International Federation for the Theory of Machines and Mechanisms (IFTOMM) here at Zakopane Poland on 27th September 1969, declare that we have founded the above-mentioned Federation and that we have adopted its Constitution which is attached hereto and decided to the following categories (see Article 8.4 of the Constitution).

| Territory | Chief delegate | Proposed Category | Signature |
|---|---|---|---|
| Australia | JACK PHILLIPS | III * | |
| Bulgaria | Georgi Rusanov | IV | |
| German Democratic Republic * | Wolfgang Rössner | III * | |
| German Federal * Republic | Werner Thomas | III * | |
| Hungary * | Zénó TERPLÁN | IV * | |
| India * | J. S. RAO | V * | |
| Italy * | GIOVANNI BIANCHI | III * | |
| Poland | Adam Morecki | IV | |
| Rumania | Nicolae I. Manolescu | IV ⊗ | |
| United Kingdom * | | III * | |
| U.S.A. | DOUGLAS MUSTER | I | |
| U.S.S.R. | | I | |
| Yougoslavia | | IV ⊗ | |

a)

Inaugural Session of the IFToMM

To be held on Sept. 27 th in Zakopane in the Conference-Hall, Nowotarska Street 45

Opening of the Session - J. Oderfeld (Poland): Greetings of the delegates and guests

Agenda

1. Report of the activity of the International Coordinating Committee on the Theory of Machines and Mechanism M. Konstantinov (Bulgaria)
2. Report of Mandate Committee – E. Stanchev (Bulgaria)
3. Report of Committee for the Distribution of UNESCO funds - N.I. Manolescu (Romania)
4. Approval of the Constitution and By-Laws – F.R.E. Crossley (USA)
5. Founding of the Federation
6. Dissolution of the International Coordinating Committee
7. Election of the members of the Executive Council – A. Morecki (Poland)
8. Closing of the Inaugural Session, and the Presidential address

b)

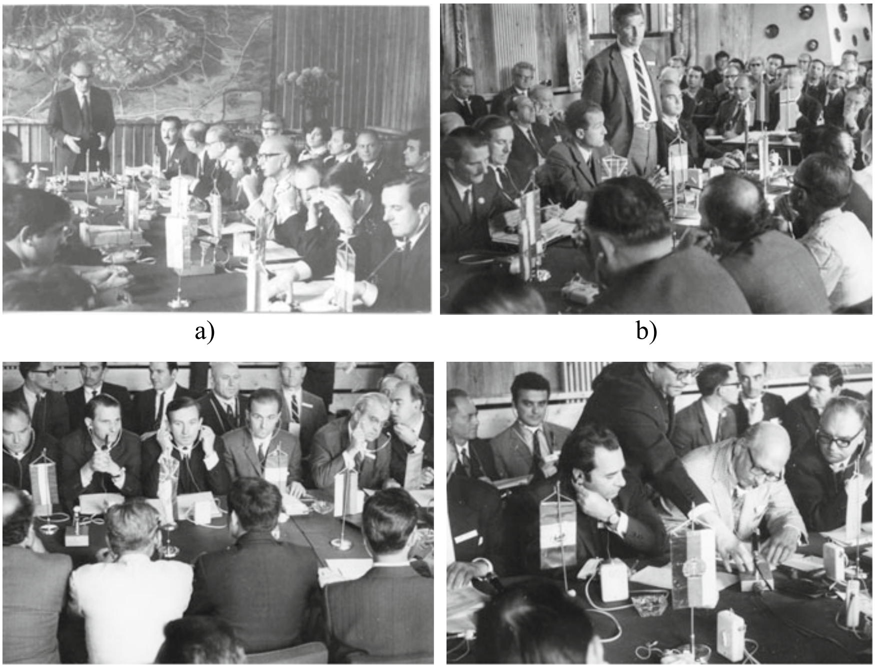
**Fig. 2** The foundation act of IFToMM, the International Federation for the Theory of Machines and Mechanisms, in Zakopane (Poland) on 27 September 1969, (Courtesy of IFToMM Archive): **a**) the signed foundation act (This unique copy of the foundation act of IFToMM was found by the author after an extensive search, even among the founding fathers of IFToMM. It was provided by professor Leonhard Maunder in 2002 during a visit of the author at the University of Newcastle upon Tyne), Table 1; **b** the agenda for the Inaugural Session, the first IFToMM General Assembly

**Table 1** The founding fathers of IFToMM, who signed the foundation act, Fig. 2a)

| | |
|---|---|
| Ac. Ivan I. Artobolevski (USSR) | Prof. Giovanni Bianchi (Italy) |
| Prof. Branislav Ilic (Yugoslavia) | Prof. Nicolae I. Manolescu (Romania) |
| Prof. Leonard Maunder (UK) | Prof. Adam Morecki (Poland) |
| Prof. Douglas Muster (USA) | Prof. Jack Phillips (Australia) |
| Prof. Jammi S. Rao (India) | Prof. George Rusanov (Bulgaria) |
| Prof. Wolfgang Rössner (GDR) | Prof. Zènò Terplàn (Hungary) |
| Dr. Werner Thomas (GFR)) | |


**Fig. 3** First IFToMM President Artobolevskii speaking at the foundation act of IFToMM, Fig. 3, (Courtesy of IFToMM Archive): 1- prof. Ivan Ivanovic Artobolevskii (USSR); 2- prof. Adam Morecki (Poland); 3: prof Kurt Luck (Germany); 4: Prof. Michael S. Konstantinov (Bulgaria); 5- prof. Nicolae I. Manolescu (Romania); 6- prof. Erskine F. Crossley (USA); 7- prof. Giovanni Bianchi (Italy); 8-prof. Aron E. Kobrinskii (USSR); 9- prof. Werner Thomas (Germany); 10- prof. Jan Oderfeld (Poland)

occasion of the second World Congress on TMM. A first World Congress on TMM (Theory of Mechanisms and Machines) was held in 1965 in Varna, Bulgaria, during which the discussion for the foundation of IFToMM made consistent progress also with the establishment of several international committees to prepare the acts for the foundation.



a) b) c) d)

**Fig. 4** Moments at first General Assembly for the foundation of IFToMM in 1969, Fig. 2: **a** prof Oderfeld starting the meeting; **b** prof Crossley giving a speech; **c** a pause with discussions; **d** signing the foundation act by delegation chairs

**Fig. 5** A group photo of main attendees at the Second World Congress in TMM on 23–27 September 1969 in Zakopane, Poland, in front of the congress site

The preparation of the constitution of the IFToMM Federation can be understood as started in 1950s' thanks also to the increased transportation facilities, that permitted several visit exchanges of professors among universities of the eastern and western blocks. That was an intense activity of visits whose aim was to fill the gap of two decades of separations among different political blocks, after the end of the second world war.

Several European professors, particularly German ones, went to USA or Russia and vice versa several Russian and American scholars and professors visited European countries with tours both for lecturing on their expertise and for searching new collaborations in revitalizing the European academic frames under reconstruction. Even within Europe there was a renewed interest in more wide collaboration and international associations were started like IUTAM at the same time of national societies or associations of universities. The above activities were experienced in all the fields of university frames and even in TMM there was an intense activity that brought to a well identified awareness of a community. The years just after the war were the incubators of the IFToMM community that was very quickly getting awareness of a need of a worldwide institution of reference. The first evident results can be recognized in official meetings and conferences as well plans for specific publication frames in United States, Russia and European countries. Thus, for example in 1953 the first specific conference on Mechanisms was held at Purdue University in USA with an international participation. Even a specific conference on teaching TMM was held in 1961 at Yale university, USA, and just later in 1966 Elsevier started the international Journal of Mechanisms as proposed by prof E. F.R Crossley, who was the first editor in Chief. The journal just after the IFToMM foundation became the official journal of IFToMM, Crossley (1972). Even in Russia several international conferences were organized mainly for the community of the eastern countries, but soon they were organized also inviting colleagues from Europe and United States. Those conferences made possible not only to exchange advances in TMM disciplines but even more to let the people (professors and young scientists) to know each other also in convivial frames, in spite of the language barriers. In those days the first World Congress on TMM was held in 1965 as a clear result of a very significant aggregation of interests and active exchange of research results in TMM. The slow motion towards on international federation was accelerated by the constraints due to the political conditions of the cold war. Contacts increased with the hopes that such an international activity could facilitate the just established frames of collaboration and visit exchanges at national and international levels, as documented in several letters that are partially stored in IFToMM archives. Main leaders in this promoting activity were prof Artobolevski from Russia and prof Crossley from USA, but with significant contribution of prof Oderfeld from Poland and prof Konstantinov from Bulgaria, as it can be understood from documents and contacts that are partially stored in the IFToMM archives. Also, many others contributed to such promoting activity, even with less evident activity, among them is worthful to remind Ferdinand Freudenstein (USA), Walter Meyer zur Capellen (Germany), Arkady P. Bessonov (Russia), Kenneth Hunt (Australia), Bindu Madhav Belgaumkar (India), just to cite some of those that are listed or not in Table 2.

Fundamental was the organization the first World Congress in Varna (Bulgaria), that was planned initially as a congress for east countries with few invited people from western countries, but it resulted a successful event where the participants discussed the terms for the federation, and they established a committee for preparing its foundation. The foundation of IFToMM as international federation of TMM was one of the main activities of the program of the second World Congress on TMM. A Generally Assembly was held and after approved the IFToMM constitution, as reported in Artobolevski et al. (1969), the first Executive Council was elected by recognizing the role of main promoters with prof Artobolevski (USRR) as president, prof Crossley (USA) as vice-president, prof Konstantinov (Bulgaria) as secretary general, prof Thomas (Germany) as treasurer, and prof Belgaumkar (India), prof Hunt (Australia) and prof Oderfeld (Poland) as members.

The new federation was structured as centered in international activity with conference organization and four commissions for specific promotion plans. Those initial commissions were Commission A for Standards with prof Muster as chair, Commission B for Education with prof Konstantinov as chair, Commission C for Collaboration with Industry with prof Teodor Pantelic (Yugoslavia) as chair, and Commission D for Conferences with prof Crossley as chair. Just after, in 1970 one more commission was started as the Commission for Publications with prof Crossley as chair and then in 1973 the Commission for History was established with prof Phillips as chair.

Those early days of IFToMM in the period from 1961 to 1975 were lived with great excitation, and significant activities were started as a reinforcement of previous friendly contacts. Immediately many other national associations were attracted to IFToMM thanks also to first successful experiences by few individuals. IFToMM was established as a promise to overpass the political barriers for a free exchange of results and experiences with a strong hope that science and technology and particularly TMM could give significant contribution to world peace and society improvements. Of course, the historical evolution of IFToMM flew continuously with personal activity and update of IFToMM officers in such a way that generations did not feel sudden changes in IFToMM. But those changes occurred and still occur because of the community evolution and its new leaders bringing characters and needs of the moments. Thus, each generation can be characterized by aspects that differentiate it from the previous and next ones, but still working with the unifying principles of collaboration and promotion for the future of the MMS community and ultimately the welfare of the mankind society.

## 3 A Short Account of History of IFToMM Towards the Future

During its fifty years, IFToMM activity has evolved in many aspects, as for example concerning the number of Member Organizations (from the 13 founder member organizations to the current 42 members), the size and scale of conference events (with many other conferences, even on specific topics, at national and international levels, in addition to the MMS World Congress), and the number and focus of technical committees working on specific discipline areas of MMS.

IFToMM was founded in 1969 and today a fourth generation of IFToMMists is coming up as those individuals can be named because working with international activity within the IFToMM community. Individuals have paid and still pay an important role on the activity and significance of IFToMM since the federation is made of people and its bodies are just an expression of the international aggregation of persons with commonly agreed rules for functioning and perspectives of activities.

In particular, Presidents and Secretaries General have had significant roles in guiding the growth and success of IFToMM. Their personalities are also representative of the IFToMMcommunity in terms of reputation and visibility worldwide. The Presidents were Ivan I. Artobolevskii (USSR), Leonard Maunder (United Kingdom), Bernard Roth (USA), Giovanni Bianchi (Italy), Adam Morecki (Poland), Jorge Angeles (Canada), Kenneth J. Waldron (USA), Marco Ceccarelli (Italy), Yoshiko Nakamura Japan), and Andres Kecskeméthy (Germany). The Secretaries General were M.S. Konstantinov (Bulgaria), Emil Stanchev (Bulgaria), Adam Morecki (Poland), Elizabeth Filemon (Hungary), Ladislav Pust (Czech Republic), Tatu Leinonen (Finland), Marco Ceccarelli (Italy), Carlos S. Lopez-Cajun (Mexico), Veniamin Goldfarb (Russia), and Teresa Zielinska (Poland).

Figure 6 summarizes the history of the IFToMM in terms of generations that have produced events in the context of associative activities with particular reference to the start of series of thematic conferences and also to the establishment of technical committees. Figure 6 shows all the technical commitees with their acronyms as well as the main thematic conferences and continental regional congresses EUCOMES for Europe, AsianMMS for Asia, and MUSME for America. More information on IFToMM and its activity can be found in the IFToMM website.

Details on the early History of IFToMM can be found in the first Chapter of Proceedings of the first International Symposium on History of Machines and Mechanisms HMM2000, (Angeles et al. 2004), in which all the past IFToMM Presidents in 2000 have outlined their historical perspectives of IFToMM in contribute papers with references of memories and acts. The history of IFToMM was also outlined in a poster exhibition during the IFToMM 2019 World Congress in Krakow, Poland (posters are in the IFToMM Archive, beside in digital form).

The IFToMM community evolved in characters from that of a family of a few enthusiastic pioneers/visionaries and founders into a scientific worldwide community as summarized in Fig. 6, through the following generations:

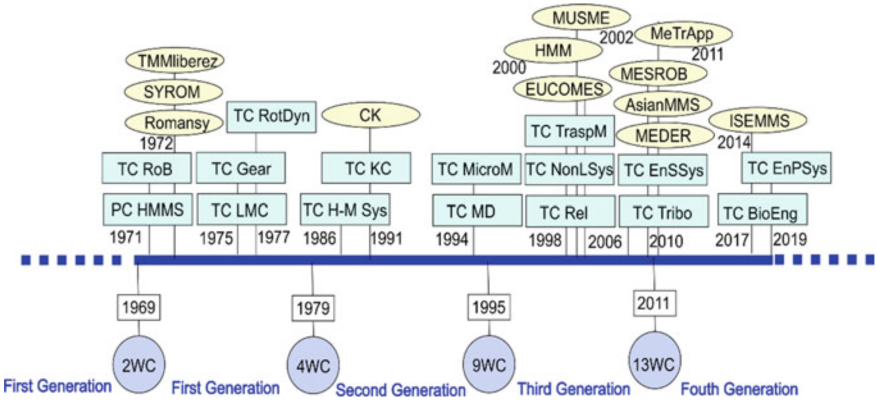



**Fig. 6** A timeline of the history of IFToMM with main facts starting of TCs and thematic Conference as function of IFToMMist generations

First generation (1960–1975): founding fathers and their friend colleagues up to the 4th IFToMM World Congress in New Castle upon Tyne in 1975 with Prof. Leonard Maunder as Congress Chair.

Second Generation (1976–1995): pupils and people, who were educated in TMM by founding fathers and their friend colleagues, up to the 9th World Congress in Milan in 1995 with Prof. Alberto Rovetta (Bianchi's pupil) as Congress Chair.

Third Generation (1996–2011): educated people with MMS activity in the frames of IFToMM and within IFToMM activity of national organizations as IFToMM members, up to the 13th World Congress in 2011 in Guanajuato, Mexico with Prof. Carlos Lopez-Cajùn as Congress Chair.

Fourth Generation (2011-Today): educated people working in frames that are linked to IFToMM and within IFToMM activity with 42 organizations as IFToMM members.

The first generation (1960–1975) was characterized by efforts in starting the activities of the Federation making clear its mission, with great hopes for future success. Most of the activity were considered and experienced for the future of IFToMM. Several new initiatives were started like regular meetings and conferences. Several EC meetings discussed long agendas with many details in even one-week of duration, as indicated in the reports that are stored in the IFToMM Archives. Significant in 1972 is the organization of the series of Romansy, CISM-IFToMM Symposium on Theory and Practice of Robots and Manipulators as the first conference event on Robotics in the world, SYROM conference as IFToMM International Symposium on Linkages and Computer Aided Design Methods, and TMM conference in Liberez as a continental conference. These conference series are still very successful IFToMM events. The Journal of Mechanisms by Elsevier was affiliated to IFToMM in 1972 and was renamed as Mechanism and Machine Theory to link it clearly to IFToMM. Several textbooks were published with titles recalling TMM or even with the name Theory of Mechanisms, in several languages around the world. Those books formed a rich literature that is today of reference for teaching, design, and research in MMS. Main topics of attention were related to Mechanisms Design in aspects for Kinematics, Synthesis, Machine Dynamics, Rotordynamics, and Robotics both as emerging fields for mechanism applications and for development of new integrated multi-discipline systems. Most of the efforts of the first generation of IFToMMists were also directed to advertising the just established federation and attracting new member organizations and more individuals as well staring new initiatives. Most of the first IFToMMists were active in IFToMM for several decades and up to their last days.

The activity of the second generation (1976–1995) is characterized by activity with a similar enthusiasm and vision to enlarge the interests and participation to the federation like by the founders with whom most of those IFToMMists were linked with direct personal experiences either as pupils or collaborators. The initiatives were aimed to enlarge both the number and participation of individuals to IFToMM activities. Other international conferences were started within the start of several TCs, like TC for computational kinematics in 1991, TC for gearing in 1976, TC for human–machine systems in 1986, TC for Mechatronic in 1994, TC for Micromachines in 1994 and TC for Rotordynamics in 1977. The participation in World Congresses (WCs) grows continuously: one with the highest number of presented papers was at the event in Milan in 1995 and one of the most socially participated ones was the one in Seville in 1987.

The third generation (1996–2011) is characterized by a worldwide presence of the community with 48 MOs in IFToMM in 2003. This growth is reflected both in renewed and revitalized activities for the already existing TCs and PCs that have culminated in a period of relevant results in the 2008–2011 term. One characteristic operation of the third generation was an extensive use of informatics means as typical of Information Age. New TCs were established in new areas of MMS, like TC for Biomechanical Engineering and TC for Energy Sustainable Systems in 2010, and a TC on Gearing and Transmissions has been re-established with a reinvigorated group of colleagues. At the end of the period of the third generation IFToMM reaches a modern location with significant influence in the world community of engineering as consequence of clear understanding and visibility of IFToMM activities. The last decade of the period was characterized by an increase of activity and correspondingly an increase of visibility, so that most of conference initiatives, mainly under MO local organization, were stimulated to be explicitly under the IFToMM umbrella. Currently a further evolution is experienced with the young generation less attracted to aggregation with society frames whereas the social media and internet provide alternative efficient chance to meet people, even in in virtual modes, for specific tasks and/or collaborations. Thus, IFToMM is facing a challenge in making of modern attraction the Federation mission and activities.

During the 15th IFToMM World Congress on Mechanism and Machine Science (MMS) in Krakow, Poland on 30 June–4 July 2019, a special opening session has been organized to celebrate the 50-years anniversary of IFToMM with unveiling of a bronze commemorative plaque, Fig. 7a. At the end of the celebration session the current IFToMM President, Marco Ceccarelli, and the Chair of the 2019 World Congress, Tadeusz Uhl, revealed the commemorative plaque, among the enthusiastic applauses of the congress attendees, first of all the members of the IFToMM Executive Council, Fig. 7b. In the 15th World Congress 637 participants from 66 countries and regions have been registered for 437 papers have been presented in a dense program with 17 topic sections of the wide domain of MMS and the most relevant to the IFToMM Technical Committees. The Springer Nature in Series Mechanism and Machine Science published proceedings of 15th World Congress proceedings in five volumes as available also in digital format.

One of the main activities for the mission of IFToMM, intended to promote the collaboration and the MMS disciplines, is related to the publication and dissemination of the results of the experiences and knowledge gained in advancing the science and technology of MMS both with congress events and with specific editorial initiatives. For this purpose, within the IFToMM, editorial collaboration activities are planned both with thematic and wide-ranging international journals (currently five are affiliated to IFToMM) and with series of books for the specific aggregation of publications. In particular, a book series on the history of MM has been active since 2007, Fig. 8a, which also refers to the Distinguished Figures series of which this chapter is part, as a historical-technical reference for all issues of interest to the IFToMM community. Following this book series, in 2011 a specific book series on MMS, Fig. 8b, was also launched by the international publisher Springer which, affiliated as the previous one to IFToMM, is an editorial frame of reference not only for the authors but also for the readers and scholars of the disciplinary subjects to which IFToMM refers.

## 4 Short Biographical Notes of Signing Founding Fathers

Below are brief biographical information and notes on technical-scientific skills of the founding fathers who signed the IFToMM Foundation together with an image that can remember their personality, suggesting the reader to deepen their cultural and technical-scientific heritage in other specific publications. These short notes are a summary of documents in the form of obituary articles or news on the activities and curriculum of the people to whom they refer as found by the author in different forms and in different repositories.


a)

b)

**Fig. 7** Celebrations of the 50th year anniversary of IFToMM in Krakow in 2019: **a** the bronze plaque; **b** the IFToMM Executive Council members with the revealed plaque

## *4.1 Academician Ivan I. Artobolevski (USSR)*

As professor at Bauman University of Moscow and Academician of Russian Academy of Science he was a worldwide reputed figure in TMM for his activities (research, teaching, and organization) and publication productions. Besides the many


a) b)

**Fig. 8** Current published book series linked to IFToMM: **a** Part 2 of the series on the Distinguished figure in the book series on History of MMS; **b** volume 1 of the MMS book series

original designs of machines and systems, his most important work is considered to be the encyclopaedic publication in 6 volumes on classification of mechanisms that has been translated into several languages all around the world. He was one of the major promoters of IFToMM and served as the first IFToMM President.

Ivan Ivanovich Artobolevski (Moscow 9 Oct 1905–21 Sept 1977)

### 4.2 Giovanni Bianchi (Italy)

Giovanni Bianchi (Milan 11 March 1924–13 Nov 2003)

Giovanni Bianchi strongly contributed to international collaboration and leadership as during his long-life activity at the Politecnico di Milano, AIMETA (Italian Society for Theoretical and Applied Mechanics), CISM (International Center of Mechanical Sciences) and IFToMM (The International Federation for the Promotion of Mechanism and Machine Science). He contributed to the foundation and successful growth of AIMETA, CISM, and IFToMM for which last he served also as President. At the Politecnico di Milano he served in research and teaching on Machine Dynamics, Vibrations, and Robot Mechanics with high-level achievements that gave him a worldwide reputation.

### 4.3 Branislav Ilic (Yugoslavia)

Nothing is known on him, more than he was professor in Beograd.

Branislav Ilic (1907–1982)

## *4.4 Nicolae I. Manolescu (Romania)*

Nicolae I. Manolescu (11 April 1907–10 October 1993)

NicolaeI. Manolescu, professor at the Technical University of Bucharest, was a worldwide reputed scientist in mechanism design with special attention in the theory for structural and kinematic analysis and synthesis of the plane kinematic chains and of various degrees of mobility mechanisms, as well as on the kinetostatic and dynamic analysis of mechanisms with results in publication of still significant impact. He was the founder of the Romanian school of Mechanism and Machine Science (MMS) and one of the main promoters and founders of IFToMM, being involved in several leadership positions. He started the SYROM conference series in 1972 within the IFToMM activities.

## *4.5 Leonard Maunder (UK)*

Leonard Maunder, professor at University Newcastle Upon Tyne since 1961, was worldwide reputed for his activities in research and international collaboration with leader positions in academic institutions as well as in research centers and governmental bodies. In particular he was President of IFToMM, in 1976–1979, after being involved in previous years in the Executive Council and in its foundation as one of the mani promoters and founders. He also organized the IFToMM World Congress in 1979 in Newcastle Upon Tyne. His scientific interests ranged in many fields of theoretical and applied mechanics such as from aeronautic systems to rotordynamics, from the dynamic analysis of mechanical systems to the design of robotic systems with a significant production of numerous articles and papers in professional journals that are still of reference. Still today are relevant his books ‘Gyrodynamics’ in 1961 (co-authored with R. N. Arnold) and ‘Machines in Motion’ in 1986 dealing with gyroscopes in very technical details and machines in natures and invented by mankind, respectively.

Leonard Maunder (10 May 1927–20 April 2019)

### *4.6 Adam Morecki (Poland)*

Adam Morecki (18 July 1923–11 Jan 2009)

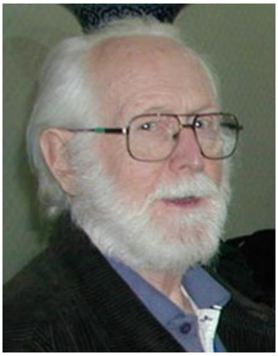
Adam Morecki, professor at Warsaw University of Technology (WUT), contributed significantly to the advancements in several fields of mechanical science with pioneering works on mechanism design, biomechanics, and robotics. Significant are his works combining robotics and biomechanics for the development of walking machines. In September 1969, Adam Morecki together with Jan Oderfeld organized the second World Congress on the Theory of Machines and Mechanisms in Zakopane, Poland, during which IFToMM was founded being him one of the main promoters and founders. Later he served in IFToMM in several leadership position up to IFToMM President.

## 4.7 Douglas Frederick Muster (USA)

(2 November 1918–7 September 2007)

Douglas Frederick Muster was professor at Houston University in Texas after having served several years in Industry with well recognized activity as engineer and designer. He served as chairman of Department of Mechanical Engineering with significant contributions to the growth of the department at national and international levels. He was involved in the founding activity of IFToMM being the signatory for the USA delegation.

## 4.8 Jack Raymond Phillips (Australia)



Jack Raymond Phillips (18 July 1923–11 Jan 2009)

Jack Raymond Phillips, professor at Sydney University in Australia, was world-wide reputed for his influential work on Screw Theory that he summarized in his books Freedom in Machinery. Among his wide interest he considered a knowledge on the discipline's history essential for building community identity so that he succeed to start the IFToMM Permanent Commission on History of TMM in 1973, after being one of the mani promoters and founders of IFToMM for which he served in several leadership positions.

## 4.9 Jammi Srinivasa Rao (India)

Prof. Jammi Srinivasa Rao, known as J.S. Rao, professor in IIT Delhi since, 1975 played a significant role in advancing design culture in private industry in India, particularly in the fields of Rotordynamics and Vibration technology with a world-wide reputation. He contributed in the foundation of IFToMM and since then he was a strong promoter of initiatives. He was Chairman for the Sixth IFToMM World Congress held in New Delhi in 1983. He was a member of IFToMM Executive Council and chair of the Rotor Dynamics Technical Committee.

Jammi Srinivasa Rao (1 July 1939–4 July 2020)

## 4.10 George Rusanov (Bulgaria)

Nothing is known of him, even in today Bulgarian IFToMM community, although at the 1969 conference in Zakopane where he was the signatory of the IFToMM foundation act for the Bulgarian delegation.

### 4.11 Wolfgang Rössner (GDR)

Wolfgang Rossner (27 June1914–???)

Wolfgang Rossner was professor since 1964 at Technische Hochschule Otto von Guericke in Magdeburg, Germany, with main research and teaching activity on the technology of mechanical transmissions with particular attention to gears and classification of related mechanisms. Supporter of international collaboration was the signatory for the GDR delegation of the founding act of the IFToMM in 1969.

### 4.12 Zènò Terplàn (Hungary)

Zènò Terplàn (25 May 1921–16 Jan 2012)

Zénó Terplán, professor at the Technical University of Heavy Industry in Miskolc covering also the position of Rector, was member of the Hungarian Academy of Sciences. His activity of research and teaching was centered on gears with strong interest on the history of engineering. He was an active promoter of international collaboration and was the signatory of the IFToMM foundation act for the Hungarian delegation.

### 4.13 Werner Thomas (GFR)

Werner Thomas (???–???)

Little is known about him also because he was employed in industry and at the time of the IFToMM foundation he was in the company Flender & Co of Bottrop near Düsseldorf t with activities of design and construction of machinery and automation. He was also very active in the German VDI association for which very probably was the chief delegate to sign the IFToMM foundation act.

## 5 Short Biographical Notes of Main Conference-Attendee Founding Fathers

Below are brief biographical information and notes on technical-scientific skills of few other (not all) founding fathers, who supported the IFToMM Foundation, together with an image that can remember their personality, suggesting the reader to deepen their cultural and technical-scientific heritage in other specific publications. Still the identification of activity and role of first IFToMMist can be considered a topic of investigation in order to recognize the activity and participation of all those who have indeed contributed to the birth and growth of IFToMM in the early days. These short notes are a summary of documents in the form of obituary articles or news on the activities and curriculum of the people to whom they refer as found by the author in different forms and in different repositories.

### 5.1 Bindu Madhav Belgaumkar (India)

Bindu Madhav Belgaumkar (1909–1989)

Bindu Madhav Belgaumkar was gentlemen professor at Indian Institute of Technology in Kharagpur from its foundation 1956 until 1970. His interests were broad in engineering but with special attention to Vibrations, Tribology and Mechanisms with significant dedication to teaching with clear diagrams and explanations on the board, forming all call of young engineers and researchers. He strong believed in international collaboration promoting also Indian Society of Theoretical and Applied Mechanics, beside being one of the promoters and founders of IFToMM to whose growth he contributed in several positions and giving to Indian community a significant role.

### 5.2 Arkady Petrovich Bessonov

Arkady Petrovich Bessonov professor at IMASH of the Russian Academy of Sciences since 1968, was worldwide reputed for his works in dynamics and vibration mechanisms and robots with a significant activity in international collaboration and mainly in IFToMM until his last days. He was one of the main promoters and founders of IFToMM and then member of the Executive Council. He was for many years the Chair of USSR IFToMM member Organization.

Arkady Petrovich Bessonov (1912–July 2017)

### 5.3 *Gerhard Bögelsack (Germany)*

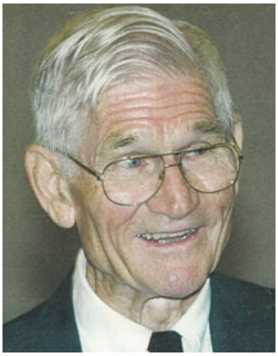
Gerhard Bögelsack (5 May 1932–28 June 2011)

Gerhard Bögelsack was professor at the TU Ilmenau, Germany, serving also at TU Niš, Serbia, with regular activity in teaching and research with main interests in gear engineering and terminology. He contributed to the foundation of IFToMM and was chairman of the commission "Standardization of Terminology" of the IFToMM producing the IFToMM milestone dictionary.

### 5.4 *Erskine F. R. Crossley (USA)*

As professor at Purdue University, he was a worldwide reputed figure in TMM for his activities (research, teaching, and organization) and community organization. Besides the many publications and machine designs with early robot designs, his most important work may be considered to be his book Dynamics in Machines

(1954). In 1969 he started the Journal of Mechanisms that is renamed since 1972 as Mechanism and Machine Theory. He was one of the major promoters of IFToMM and served as the first IFToMM Vice-President.



Francis Rendel Erskine Crossley (21 July 1915–4 February. 2017)

## *5.5 Günter Dittrich (Germany)*

Gunter Dietrich (1935–21 November 2016)

Gunter Dietrich, professor and director of the Institute of Mechanism Science and Machine Dynamics at RWTH Aachen University after industrial experience at Robert Bosch GmbH in Bühlertal, was reputed for this teaching and research activity on kinematics and dynamics of mechanisms as well as robotic systems. He was also very activity in the German VDI professional association, even with leadership positions. His international activities were among others dominated by his participation to IFToMM reaching the position of member of the Executive Council and Chair of the Technical Committees "inkages and cams".

### 5.6 Florea Duditza (Romania)

Florea Duditza, professor at the University of Braşov, worked an intense activity on teaching and research on all aspects of mechanisms, including history of mechanical engineering with several publications of still significant impact at national and international levels. He was very active in IFToMM where he contributed to many TCS and particularly to TC linkages and Cans. He was awarded in 2010 of the IFToMM Award of merit.

Florea Duditza (12 April 1934–living)

### 5.7 Kenneth Henderson Hunt (Australia)

Kenneth Henderson Hunt (7 June 1920–21 Aug 2002)

Kenneth Henderson Hunt was professor at Monash University in Melbourne, Australia, where he moved after service during the World War II and employments in British industry, being born in England. There he was very active in teaching, research and organization of the academic frames with a frequent travelling overseas also for teaching and research collaborations. He stared the first Chair of Mechanism in Australia as related to the main interests of his research and teaching activities. He was well reputed for his significant works on mechanism design with particular attention to a modern Screw Theory whose results in publication are still for reference in the field. He was active in IFToMM since the early days of the Federation contributing to conferences event and promoting the Australian community in that international frame.

## 5.8 *Ichiro Kato (Japan)*

Ichiro Kato, professor at Waseda University in Tokyo, called the "father of Japanese robotics research", was well reputed all around the world for his achievements in Robotics not only for WABOT, the first humanoid robot starred in 1972. He is well known for his works in biomechanics and early mechatronics combining the disciplines in pioneering design of robotic and medical devices. In this area he started a strong school at Waseda University with Humanoid Robotics Institute established in 2000 that has been emulated all around Japan. He strongly believed in international collaboration so that he travelled frequently overseas not only to present his works but to contribute to an international community. He served in leader positions in several institutions in Japan and abroad, also collaborating in international conference initiative. Emblematic is his early active participation at CISM-IFToMM Romansy symposium in 1972 as the first conference event in Robotics. As well he was strongly interested in the IFToMM Federation since its foundation, having participated at 1969 Zakopane conference, although only later Japan became IFToMM member organization.

Ichiro Kato (1935–19 June 1994)

## 5.9 *Kurt Luck (Germany)*

Kurt Luck (21 March 1931–3 July 201)

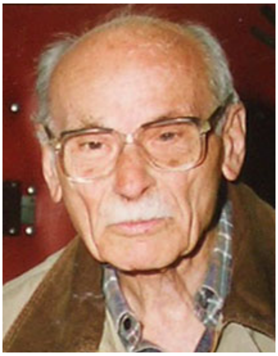
Kurt Luck, professor at Dresden University of Technology, was well known all around the world for his works on Theory of Mechanisms with particular interest in linkages and Burmester theory, thanks also of a continuous international collaboration with frequent visit exchange. After Prof. Lichtenheldt retired in 1967, Prof. Luck became his successor preserving the passion for IFToMM that gave the to actively contribute to IFToMM growth up to being elected member of the IFToMM Executive Council, and chair of the IFToMM Technical Committee "Linkages and Cams". He also was very dedicated to record the vents and made a rich archive of photos of great values also for the History of IFToMM, starting from the days of the IFToMM foundation in 1969.

### 5.9.1 Michael Spirov Konstantinov (Bulgaria)

Michael Spirov Konstantinov (22 March 1921–8 April 1991)

As professor at Sofia University, he was a worldwide reputed figure in TMM for his activities in research, teaching, and organization on wide area of mechanical engineering with first robot designs and community organization. In 1973 he started the first laboratory on Robotics. He was one of the major promoters and founders of IFToMM and served as the first IFToMM Secretary General.

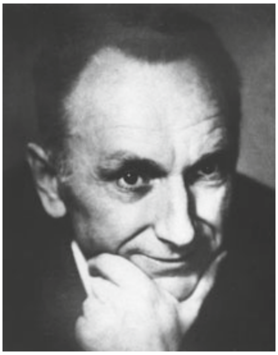
### 5.9.2 Jan Oderfeld (Poland)



Jan Oderfeld (9 February 1908–17 March 2010)

As professor at Technical University of Warsaw he was a worldwide reputed figure in TMM for his activities in research, teaching, and organization on mechanical engineering at large and in publication productions with an early team properly focused on TMM. His most important design can be considered the development of an early jet engine. He was one of the major promoters and founders of IFToMM and organizer of the 1969 TMM World Congress in Poland where IFToMM was founded.

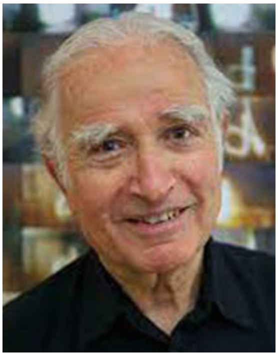
### 5.9.3 Zdzislaw Parszewski (Poland)



Zdzislaw Parszewski (25 May 1924–16 May 1999)

Zdzislaw Parszewski was professor at Technical University of Lodz where contributed to start a new Machines and Mechanical Theory Scientific Group with academic and professional collaborations all around Poland until he moved in 1981 at the Mechanical Department of Technical University of Melbourne in Australia where he retired in 1989. His research activity was centered on dynamics of rotor machines, vibrations and automation with significant results published in many scientific publications, also for industry use and students' textbooks. He was also one of the initiators and later strong promotor of Polish Society of Theoretical and Applied Mechanics being elected also director of it. He was one of the promotors and founding fathers of IFToMM being also Chair IFToMM Member Organization Poland for many years.

### 5.9.4 Bernard Roth (USA)



Bernard Roth (28 May 1933–living)

Bernard Roth (in short Bernie) is professor of Engineering at Stanford University since 1962 where he arrived from New York City. He has a worldwide reputation as a researcher in kinematics and robotics for the many influential pioneering achievements in mechanism design with particular focus on robotics and mathematical theory of rigid body motions and its application to the design of machines. Since 2005, he devotes his efforts and time in the so called d.school on creativity, group interactions, and problem solving process. Since the beginning of his academic career, he promoted international collaboration even recruiting PhD students from all around the world, beside lecturing and visiting many universities and cities in the five continents. He has been a very active IFToMMist since the early days of IFToMM foundation contributing to many initiatives and covering many leaderships up to being elected IFToMM President.

### 5.9.5 Yuri Sargsyan (Armenia)

Yuri Sargsyan (9 February 1941–living)

Yuri Sargsyan, professor at State Engineering University of Armenia (SEUA), is a well-known MMS scientist with activity in the theory of synthesis of mechanisms and computer-aided design, theory of spatial mechanisms, mechanics of robots and automation systems whose results are published in publication of significant impact. Formed in Moscow institutions, he came back to Armenia where he started a successful activity in teaching, research and organization that leads him to leadership position as rector of his university and of the Armenia community, today organized in IFToMM member organization. Beside his activity in international frames with recognized positions and awards, he has contributed with his participation to the IFToMM growth since the early days when as PhD student took part at the 1969 Zakopane conference of the foundation and then he served as member of the IFToMM Executive Council, Chairman of the Armenia IFToMM Member Organization and members of several TCs and of the Permanent Commission for Standardization and Terminology.

## 6 Conclusions

This chapter contains very brief notes on the biography and the technical-co-scientific profile of the founding fathers of IFToMM together with a brief outline of the events and history the refer to the foundation of the IFToMM in 1969. The founding fathers of IFToMM can be identified in those pioneers of the international associative aggregation in the field of mechanical engineering with particular reference to the science of machines and mechanisms who were the promoters at the forefront and therefore also signatories of the foundation together with colleagues who without having the visibility of the official act, however, made a significant contribution to the foundation of IFToMM. The short biographical and technical-scientific profile notes of the founding fathers are also intended to be an act of historical memory as well as a stimulus to remember and evaluate the personalities of past generations who contributed to the development of science and technology in machines of mechanisms and to include in the historical research subjects of mechanical engineering also the biographical and technical-scientific documentation of the personalities who can be taken as a reference for future generations.

## Appendix

The founding fathers of IFToMM as conference attendees, Chair of TMM (1969).

| Eng. A. Balashev (Bulgaria) | Eng. E. Preusser (GDR) |
|---|---|
| Eng. T. Venkov (Bulgaria) | Eng. K. Reinsberg (GDR) |
| Ass. Prof. A. Vrigazov (Bulgaria) | Eng. K. Schirmeister (GDR) |
| Ass. Prof. K. Enchev (Bulgaria) | Dr. D. Stundel (GDR) |
| Eng. P. Genova (Bulgaria) | Missed pages 6 and 7 with lists of |
| Mr. M. Milkov (Bulgaria) | participants from GFR, India, Italy, |
| Ass. Prof. E. Stanchev (Bulgaria) | Lithuania, Netherlands, Norway, |
| Eng. P. Zakharev (Bulgaria) | and some from Poland |
| Dr. V. Brat (Cech Republic) | Dr. J. Dekert (Poland) |
| Eng. V. Chaloupka (Cech Republic) | Dr. Z. Engel (Poland) |
| Eng. O. Jandl (Cech Republic) | Dr. R. Godlewski (Poland) |
| Dr. L. Prasek (Cech Republic) | Dr. J. Golinksi (Poland) |
| Eng. J.Sima (Cech Republic) | Dr. R. Gutowski (Poland) |
| Eng. W. Stejskal (Cech Republic) | Dr. M. Hincz (Poland) |
| Eng. J. Stejskal (Cech Republic) | Dr. B. Jagiello (Poland) |
| Eng. F. Svoboda (Cech Republic) | Dr. A. Jakubowixz (Poland) |
| Dr. A. Tondl (Cech Republic) | Mr. J. Juncha (Poland) |
| Prof. A.D. de Pater (Netherlands) | Dr. E. Kaminski (Poland) |
| Prof. I. Kato (Japan) | Dr. K. Kedzior (Poland) |
| Dr. Banke (GDR) | Dr. J. Krodkieeski (Poland) |
| Dr. H. Boden (GDR) | Mr. T. Kopyt (Poland) |
| Dr. H. Broeke (GDR) | Dr. b. Kowalczyk (Poland) |
| Prof. A. Bock (GDR) | Dr. W. Kurowski (Poland) |
| Prof. G. Bogelsack (GDR) | Dr. A. Kwasnicki (Poland) |
| Eng. G. Christen (GDR) | Prof. A. Morecki (Poland) |
| Prof. J. Volmer (GDR) | Dr. S. Miller (Poland) |
| Dr. Ch. Hammerschmidt (GDR) | Dr. A. Muszynska (Poland) |
| Dr. A. Holfeld (GDR) | Dr. W. Nadolski (Poland) |
| Eng. W. Heydt (GDR) | Dr. K. Nazarczuk (Poland) |

(continued)

(continued)

| Eng. A. Balashev (Bulgaria) | Eng. E. Preusser (GDR) |
|---|---|
| Prof. F. Holzweissig (GDR) | Dr. J. Nowosielki (Poland) |
| Eng. H. Hugk (GDR) | Prof J. Oderfeld (Poland) |
| Dr. H. Hilpert (GDR) | Dr. A. Oledzi (Poland) |
| Dr. W.Ihme (GDR) | Prof. W. Olszak (Poland) |
| Dr. F. Janitzek (GDR) | Dr. R.Osinski (Poland) |
| Dr. G. Kunad (GDR) | Dr. Z.Ozimowski (Poland) |
| Eng. F. Kohler (GDR) | Prof. Z. Parszewski (Poland) |
| Prof. W. Lichtenheldt (GDR) | Dr. T. Piech (Poland) |
| Prof. K. Luck (GDR) | Dr. W. Pogorzelski (Poland) |
| Eng. S. Liebig (GDR) | Dr. Z. Rotter (Poland) |
| Dr. J. Muller (GDR) | Dr. M. Roszkowski (Poland) |
| Eng. S. Mende (GDR) | Dr. J. Stelmarcyk (Poland) |
| Eng. H. Nowak (GDR) | Dr. W. Stojanowksi (Poland) |
| Dr. K. Tempinski (Poland) | Ac. I.I. Artobolevsky (USRR) |
| Dr. K. Tomaszewski (Poland) | Mr. V.K. Astashev (USRR) |
| Dr. Z.Walczak (Poland) | Mr. V. Babitsky (USRR) |
| Eng, Z. Waserzrtrum (Poland) | Mr. Y.D. Baltrushaytis (USRR) |
| Dr. J.Wawrzecki (Poland) | Prof. A. P. Bessonov (USRR) |
| Mr. W. Wisniewski (Poland) | Prof. V. L. Veits (USRR) |
| Dr. W. Wisniewski (Poland) | Prof. M. IVoskresensky (USRR) |
| Dr. W. Wodzicki (Poland) | Mr. I.B. Vinogradov (USRR) |
| Dr. M. Zabawa (Poland) | Mr. M.M. Hernet (USRR) |
| Dr. K. Zieba (Poland) | Mr. N. Grigoryev (USRR) |
| Dr. T. Zielinski (Poland) | Prof. L.S. Grodzenskaya (USRR) |
| Dr. A. Bosznay (Hungay) | Prof. A. Zheligovsky (USRR) |
| Prof. I. Salyi (Hungay) | Mr. M.Y. Izrailovich (USRR) |
| Prof. Z. Terplan (Hungay) | Prof. I.A. Klusov (USRR) |
| Dr. A.D.S. Barr (Great Britain) | Prof. A. Kobrinsky (USRR) |
| Dr. J. Fawcett (Great Britain) | Prof. N.A. Kovalev (USRR) |
| Prof. L. Maunder (Great Britain) | Prof. S. N. Kozhevnikov (USRR) |
| Dr. M.R. Smith (Great Britain) | Mr. A.S. Koliskor (USRR) |
| Prof. S.S. Beggs (USA) | Mr. A.I. Korenyasev (USRR) |
| Dr. M.L. Chu (USA) | Mr. N.N. Krasnoshchekov (USRR) |
| Prof E.F. R. Crossley (USA) | Prof. O.I. Kulbachny (USRR) |
| Dr. I. Einstein (USA) | Prof. N.I. Levitsky (USRR) |
| Prof. E. Garnet (USA) | Mr. E.N. Levkovsky (USRR) |
| Prof. L. Harrisberger (USA) | Mr. A.V. Orlov (USRR) |

(continued)

(continued)

| Eng. A. Balashev (Bulgaria) | Eng. E. Preusser (GDR) |
|---|---|
| Prof. C.Y. Ho (USA) | Prof. L.G. Ovakimyan (USRR) |
| Prof. B. Roth (USA) | Prof. G.N. Petrov (USRR) |
| Prof. A.T. Yang (USA) | Prof. V.F. Preis (USRR) |
| Prof. K.C. Hsei (USA) | Prof. V.A. Pimenov (USRR) |
| Prof. D. F. Muster (USA) | Prof. S.V. Pinegin (USRR) |
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# Correction to: Carlos López-Cajún (1948–2020)

**Marco Ceccarelli and Juan Carlos Jauregui Correa**

## Correction to:
## Chapter "Carlos López-Cajún (1948–2020)" in: M. Ceccarelli and A. Gasparetto (eds.), *Distinguished Figures in Mechanism and Machine Science, History of Mechanism and Machine Science* 41, https://doi.org/10.1007/978-3-031-18288-4_4

The original version of this chapter unfortunately contained a mistake. The author Juan Carlos Juaregui Correa name was incorrect. The correct name should read: "Juan Carlos Jauregui Correa" The chapter and book have been updated with the changes.

The updated original version of this chapter can be found at https://doi.org/10.1007/978-3-031-18288-4_4



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