History of Mechanics

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Abstract This chapter presents the evolution of research in Romania on the mechanics (the mechanics of rigid solids, deformable solids in elastic, elastoplastic or plastic behavior regimes, the theory of mechanical vibrations, fluid mechanics) but also closely related problems such as the theory of mechanisms, contact mechanics, construction of hydraulic equipment. The important stages in the development of these scientific disciplines are highlighted, the emergence of new disciplines such as tribology, chromoplasticity, the personalities and schools they created. In the same time the theoretical and experimental contributions of Romanian researchers to the progress of mechanics and industry, laboratories, works and published treatises are highlighted.

1 History of the Mechanics of Rigid Bodies

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The mechanics of rigid bodies (rational mechanics, theoretical mechanics) appeared initially as applied mechanics or technical mechanics. The first results can be traced back at least 3000 years. In those early ages, technical knowledge embedded with simple notions of mathematics started to be applied to the design and construction of simple machinery, including means of transportation and devices to reduce hard human labor or to harvest the forces of nature.

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Theoretical mechanics is the first of the physical sciences to have received a theoretical foundation in the 1687 *Philosophiae Naturalis Principia Mathematica* thanks to the genius of Isaac Newton (1642–1727)—mathematician, physicist, astronomer and philosopher. Very few scientific theories have gathered such commanding authority as Newton's works.

On the current territory of Romania, knowledge of practical mechanics has been attested by archaeological discoveries proving the utilization of simple machinery and transportation means from the earliest ages. The first written documents are from the 16th century and were about rocket ballistics. A manuscript describing research of Conrad Haas (1529–1579) on multistage rocket propulsion (Andonie 1965, 1966, 1967, 1971, 1981; Bălan and Mihăileanu 1985; Iancu 2009) is held at the Library of the Bruckenthal Museum in Sibiu. The first published work to contain elements of theoretical and practical mechanics is professor S. Pataky's work dating 1773 (Wolff 1773). Notions of theoretical mechanics have been taught at the highest education institutions of the time: the Academies in Iași and Bucharest beginning with the middle of the 18th century, following the works by Descartes *Principles of Philosophy* (1614) and *An explication of machines by means of which one can lift with a small force a very heavy load* (1637), and mainly the works by Newton. At the Academy in Iași, N. Cercel lectured Experimental Physics and Newtonian Gravity Theory from 1760 to 1773, while N. Theotochis lectured physics with elements of mechanics from 1764 to 1767. The latter published his first modern physics treatise titled *Elements of Physics* in Leipzig, 1765, written in Greek, in two volumes and including mechanics. The earliest nationally published work to contain elements of mechanics (at the end of the 18th century) is Manuscript 1081 from the Romanian Academy Library, also written in Greek. The manuscript contains 225 pages, is not titled and belonged to a certain Dr. M. Gaster. The content related to mechanics includes the motion under the action of gravity, the law of the lever and simple machineries.

The first book to present the fundamental principles of classical mechanics to the Romanian public was written by Gh. Șincai and took after Helmuth's *Physics* (around 1809). The first professor of mechanics was engineer Al. Costinescu who taught in Romanian at the Academia Mihăileană in Iași during 1837–1838. In 1842 the printing house of Sf. Sava College published *Moș Pătru sau Învățătorul din sat. Convorbiri asupra mecanicii* dedicated to teaching notions of mechanics in elementary schools (Marin 1881).

The evolution of theoretical mechanics in our country is directly related to the evolution of higher education. Prior to 1848, technical higher education was in its dawns as its scope had been limited to training agents for various public works (as noted by C. Bușilă in 1918). In Bucharest, a College of Exact Sciences was established in 1850 having three specialties: Topography, Bridges and Roads, and Architecture. In 1852, at the request of the ruling prince of Ţara Românească, the French Government sent L. Lalanne, a graduate of the School of Bridges and Roads, to Bucharest. He organized the system of public works after the French one and founded a post-secondary engineering school in Bucharest. He also introduced the metric system of measurements, organized the Postal and Telegraph Services, as well as the Public Works Corps of Engineers, and coordinated preliminary studies for the construction of railways (Voinea and Voiculescu 2004). In Moldova, Gh. Asachi has established the Applied School of Engineers and Conductors, with a duration of studies of three years.

The real development of higher education in Romania is linked to the period after the Unification of 1859, when major universities were founded. University of Iași was founded on September 26, 1866, and included a Department of Sciences where mechanics has been taught by Melik et al. (1865–1913), Vâlcovici (1913–1921) and S. Sanielevici. From 1938–1945, physicist I. Plăcințeanu, Ph.D. in sciences from the University of Gottingen, taught mechanics at Iași. He published *Relativistic Effects Derived with a Novel Theoretical Mechanics*, where he refers to the *Invariantive Mechanics* developed by O. Onicescu. In 1942, Plăcințeanu published *Mecanică rațională și analitică* (Plăcințeanu 1942), a book of great scientific value. O. Onicescu—the first Romanian to hold a Ph.D. in mathematics from Italy (1920)—made great contributions to the field of theoretical mechanics (Onicescu 1956), relativistic mechanics and statistical mechanics. In his work *Mecanica invariantivă și cosmologie* (Onicescu 1974), he develops a novel mechanics of material systems.

The University of Bucharest was founded in 1864, and included a Department of Physical, Mathematical and Natural Sciences. A dedicated Department of Mechanics has been created in 1880, the discipline of rational mechanics being taught by Haret (1878–1911), Lalescu (1911–1912), Pompeiu (1912–1930) and Vâlcovici (1930–1962). In 1878, Spiru Haret becomes the first Romanian to obtain a Ph.D. in Mathematics from Sorbonne, Paris. Later, acting as the Minister of Public Instruction he introduced reforms of secondary and higher education (1898), and vocational education (1899). His book *Mécanique sociale* (Haret 2010), published in Paris in 1910, has been praised by French sociologist G. Richard.

V. Vâlcovici was the first to use a vector expression in theoretical mechanics. His vast works encompass mathematics, theoretical mechanics, and mostly fluid mechanics. At the Polytechnic School of Timișoara and the University of Bucharest, he introduced modern mechanical laboratories. The treatise *Mecanica teoretică* (Vâlcovici et al. 1958) authored by V. Vâlcovici, Șt. Bălan and R. Voinea with contributions from O. Dragnea, R. Voinaroski, P. Mazilu, Al. Stoenescu, S. Pop and E. Beiu-Paladi represents a work of exceptional scientific importance. In 1938, The Romanian Academy opened a new series of scientific monographs with the works *Ecuațiile mecanicii analitice* by N. Ciorănescu, licensed in Sciences and Ph.D. in Mathematics from Sorbonne in 1924. The preface was written by Gh. Țițeica.

At the National School of Bridges and Roads, later on the Polytechnic School of Bucharest, during 1908–1937 in charge of mechanics was A. Ioachimescu, licensed in mathematics (Paris, 1894). His lectures, rich in engineering content, have been published posthumously in 1947 by his successors Al. Stoenescu and G. Țițeica. I. Ionescu and T. Lalescu, from the same university, made important contributions to the development of theoretical mechanics.

At the University of Cluj, founded in 1911, V. Desmireanu, General Șt. Burileanu, D.V. Ionescu and C. Iacob. taught theoretical mechanics courses. Șt. Burileanu, who earned a Ph.D. in mathematics from Paris, wrote *Curs de mecanică rațională*

(Burileanu 1942, 1944) in 1942, and *Curs de mecanică rațională. Volumul II Dinamica* in 1944. Remarkable works have also been published by D.V. Ionescu, who earned his Ph.D. from Sorbonne, Paris.

The rational mechanics courses at the Polytechnic School of Timișoara, founded in 1920, have been taught by C. C. Teodorescu, V. Vâlcovici, Șt. Drăgănescu and M. Ghermănescu. Mathematician by formation, M. Ghermănescu made important contributions to the field of mechanics. He published *Probleme și propoziții din dinamica punctului* in 1943, and lectures of mechanics. References Ionescu (1932), Mihăiță et al. (2000), *** (1979) give additional information on the historical evolution of teaching and research in the field of classic mechanics.

During 1948–1963, The Romanian Academy had a common Section of Mathematics and Physics that was split in 1963. The regional affiliates in Iași, Cluj and Timișoara had sections dedicated to applied mathematics, and scientific and technical research. Starting with 1948 the applied research activities have been promoted and extended to universities and research institutions leading to some noteworthy results. Mathematician D. Mangeron from the Polytechnic Institute of Iași had contributions in analytical mechanics, in collaboration with N. Irimiciuc. The technical literature retains the equations of Mangeron-Tenov. A. Ripianu, from the Polytechnic Institute of Cluj, studied rotor-dynamics; in collaboration with C. Tudose he studied the central motion of material point. Al. Stoenescu, professor at the Polytechnic Institute of Bucharest, published several works on rocket motion, the motion of Earth artificial satellites, the theory of the gyroscope, and the theory of relativity. R. Voinea, Rector of the Polytechnic Institute of Bucharest and President of The Romanian Academy, has established a veritable school of applied mechanics. He has published books in classic mechanics, strength of materials, theory of elasticity, and theory of mechanisms. R. Voinarovski, from the Oil and Gas Institute of Ploiești has studied the kinematics of rigid systems in a four-dimensional Euclidian space. In collaboration with L. Teodoriu he built an apparatus to determine the acceleration of gravity: the Teodoriu-Voinarovski pendulum. Șt. Bălan, from the Civil Construction Institute of Bucharest, published on new construction materials, as well as textbooks and collections of exercises in solid mechanics. Gh. Silaș, of the Polytechnic Institute of Timișoara has contributions in collisions and percussions, dynamics of machinery and nonlinear dynamics. He has established a research group in vibro-impact dynamics.

Starting with 1990 deep changes affected the entire Romanian society including the fields of education and research. Universities added Master programs in solid mechanics. There was a spike in publications at major printing houses in the country and abroad: *Introducere în teoria sistemelor dinamice* (Voinea and Stroe 2000), *Elemente de mecanică analitică* (Ursu-Fischer 2015), *Mechanical Systems. Classical Models* (Teodorescu 2009a), *Dynamics of the Rigid Solid with General Constraints by a Multibody Approach* (Pandrea and Stănescu 2015), *The Optimal Homotopy Asymptotic Method. Engineering Applications* (Marinca and Herişanu 2015).

Research in the field continues nowadays on fundamental aspects of mechanics, as well as topics of a broader perspective. Problems in dynamic systems control, multibody dynamics, theory of threaded fasteners applied to mechanics have been tackled by research teams led by T. Sireteanu and V. Chiroiu at the Solid Mechanics Institute, by N. Pandrea and N. D. Stănescu at the University of Pitești, and by S. Vlase at the University Transilvania of Brașov. At the Polytechnic University of Timișoara, the research carried out by V. Marinca and N. Herișanu is related to nonlinear mechanics, asymptotical methods and the inverse problem in analytical mechanics. Professors N. Plitea and D. Pâslă from the Technical University of Cluj-Napoca have contributions to the mechanics of parallel mechanisms used in robotics.

2 History of Mechanisms

Iulian POPESCU

Throughout time, people built themselves devices, appliances, machines, in order to process raw materials and products, to build houses, to create weapons, etc. Until the 18th century, mechanisms were built empirically, by people gifted with technical creativity. However, mechanisms were created in *antiquity* that also required some calculations, but they did not survive to our days. During the *Middle Ages* machine builders used the forces of water, wind and animals (Agricola 1994). The bases of calculation methods for mechanisms were set starting with the 18th century (with the research carried out by Euler, Monge and others). The emergence of steam machines was a strong drive for the mathematical and engineering research of mechanisms. The beginnings of the theory of mechanisms were laid by mathematicians (Euler established the law of gearing in 1765, Monge created a theory of mechanical engineering, also establishing a ranging of mechanisms, etc). Throughout this period, researchers did not benefit from the calculation techniques in order to tackle the difficult problems of mechanisms, so they *turned to graphic methods.* These methods, extremely laborious and with a low accuracy, slowed calculation techniques for mechanisms, so that most engineers chose simplified calculations, despite the fact that machines became more and more complicated. Graphic methods were used for many years, becoming more and more complicated, thus reaching a limit in mechanisms' research. The German school and partially the French one, took the lead in mechanisms' engineering between 1914 and 1941. Graphic and graphical-analytical methods expanded, drawing up complicated methods, but more simplified methods were also found, enabling some engineers to carry out partial calculations for certain mechanisms. The experience acquired in machine engineering and building gained force, but the discipline of Mechanisms was still included in Theoretical Mechanics, as application for certain theoretical problems, leading to the emergence of Applied Mechanics.

In 1948, Polytechnic schools of București, Iași and Timișoara became Polytechnic Institutes, such institutes being created in other cities as well. The Theory of mechanisms as a subject emerged from Theoretical Mechanics, which enabled the training of specialized professors and establishing academic and experimental labs.

Among the first Romanian books on mechanisms, it is worth mentioning the ones of Lazaride (1953), N. Manolescu (four volumes lithographed by CFR Publishing House between 1955–1956) (Manolescu 1955–1956; Maros (1953, 1958), and N. Manolescu and D. Maros on kinetostatics and dynamics (1958) (Manolescu and Maros 1958). In 1959, professor V. Manafu published the book 'Structura și cinematica mecanismelor' (Manafu 1959), where he presented the current status of researches in the field of the theory of mechanisms and also original contributions regarding the prevalence of the similarity method to kinematics, the method for binding mechanisms and others. It is interesting to notice that during a 1989 symposium, professor N. Manolescu explained that professor V. Manafu was not mentioned as the author of the book, given the political context of that time. Several collections of problems were very useful in applying the theory of mechanisms: Conţiu 1957, Manolescu and all (1963–vol. I, 1968–vol. II) (Manolescu et al. 1963).

In September 1965, in Varna, Bulgaria, a conference was held on 'Mechanisms and Machines' where the creation of an International Federation for the Theory of Machines and Mechanisms was proposed. With the help of professor N. Manolescu, Romania was a founding member of this federation.

The first meeting of Romanian mechanical specialists was organized in 1972 by professor F. Kovacs from Timișoara, the symposium being held in Reșița, and it was called 'Mechanisms and mechanic transmissions. In 1973 the first International Symposium on Mechanisms was organized—SYROM '73 (held on an ongoing basis every 4 years, and was still organized, in Brașov, for the past few years).

During the 70s, with the emergence and use of computers, technical calculations were developed, enabling researchers to use numeric methods instead of graphic ones for analytical methods, programmed in Fortran (I. Simionescu) or Basic (I. Popescu) or other software (C. Pelecudi). A significant number of books on mechanisms were published by authors like: D. Tutunaru, N. Manolescu, F. Kovacs, A. Orănescu, F. Dudiță, E. Diaconescu, G. Gogu, V. Sandra-Luca, I.A. Stoica, D. Maros, etc. It was in this period that Romania developed the first researches in the field of Industrial Robots, in Timișoara (Prof. F. Kovacs), Bucharest (Prof. C. Pelecudi), Iași (prof. D. Mangeron) and other centers in the country.

Romanian Figures in the Field of Mechanisms

The Polytechnic of Bucharest developed a school of theory of mechanisms where a significant number of researchers was trained: N. Manolescu, C. Pelecudi, R. C. Bogdan, T. Demian, D. Tutunaru, etc. Professor N. Manolescu had an immense contribution to kinetics: the issue of scales in graphic and analytical calculations, the similarity method, synthesizing kinetic chains of different families, speed and acceleration distribution for mechanisms with complex kinematic chains and many others. Professor C. Pelecudi published two fundamental books with Editura Academiei Publishing House, on the basis of mechanism analysis and the theory of spatial mechanisms (Pelecudi 1972, 1975), supporting analytical methods and also being a pioneer of applying calculation techniques in solving problems pertaining to the theory of mechanisms. In 1969, professor D. Tutunaru published a monograph on cam mechanisms (Tutunaru 1959) and another on rectilinear mechanisms and inverters

(Tutunaru 1969), presenting a series of original contributions. Professor R. C. Bogdan analysed mechanisms through experimental mechanical and electric methods using harmonics analysis (Bogdan 1968) and professor T. Demian studied mechanisms of fine mechanics (Demian 1965). Apart from researches in theoretical mechanics, professor D. Mangeron from Iași, also published books on mechanisms, such as the study of reduced acceleration for planar and spatial mechanisms, the similarity method, the tensor method and others (Mangeron and Irimiciuc 1978). He coordinated the publication titled Scientific Bulletin of the Polytechnic Institute, an internationally known journal, and trained important researchers in mechanics and mechanisms. In Timișoara, professor F. Kovacs developed new methods for mechanism analysis and synthesis (Kovacs et al. 1976) and created an important school specialized in industrial robots. At the same time, professor D. Perju left his mark on mechanism analysis and synthesis, especially as regards the mechanisms with top kinematic coupling. In Cluj-Napoca, professor D. Maros established a school specialized in mechanisms, focused on gear kinematics (Maros 1958) and mechanisms with top kinematic coupling. Professor I. Szekelly handled mechanisms of fine mechanics and new calculation methods (spline functions) and others. Professor V. Handra-Luca's researches were published in a treaty on transmission functions (1983) (Handra-Luca 1983), as well as in a two-volume monograph (1983) (in collaboration with I.A. Stoica) (Handra-Luca and Stoica 1983), publishing at the same time a number of papers both nationally and abroad. The school in Brașov was lead by professor F. Dudiță—who contributed to the field of universal joints (Dudiţă 1966a) (translated in French (Dudiţă 1966b) and German (Dudiţă 1973)), mobile homokinetic couplings (Dudiţă, 1974), hinged mechanisms (Dudiţă et al. 1989)—initiated the study of biomechanisms and of the history of mechanisms in Romania. This school trained specialists who handled motor car mechanisms (Alexandru et al. 1977), as well as other various mechanisms (G. Gogu, I. Vișa). Professor A. Orănescu, from the University of Galați, developed methods of kinematic calculations for complex kinematic groups (Orănescu 1963). Professor N. Pandrea, from the University of Pitești had original contributions to kinematics and the synthesis of spatial mechanisms (Pandrea and Popa 2000), machine dynamics, and integration of motion equations, and analysed the dynamics of Gogu Constantinescu's torque converter. Professor I. Popescu (University of Craiova) greatly contributed to the structural synthesis of mechanisms (Popescu 1977), kinematics and computer assisted analytical kinetostatics, biological mechanisms (Popescu et al. 1977), the history of mechanisms (Popescu 2011), aesthetics in mechanisms, etc.

3 History of the Mechanics of Deformable Solids

3.1 Theory of Elasticity

Costică ATANASIU

The mechanics of deformable solids—name under which the strength of materials and the theory of elasticity are known in the scientific literature—is a discipline of engineering. The main goal of the first discipline—strength of materials—is to obtain the stress and strain state in bars and systems of bars subject to external loads, using different hypotheses. The dimensions of a cross section are calculated taking into account the characteristics of the material, in order to ensure that the bar will resist during service. The theory of elasticity studies the stress and strain state in deformable solids considering the material as a continuum displaying a linear elastic behaviour under external loads.

In Romania, the French education system was implemented by Romanian former students who studied in France (Andonie 1965; Atanasiu 2017; Leonăchescu 2011). Written documents on the mechanics of deformable solids published in Romania show that a course of theoretical and applied mechanics was taught (Andonie 1965) in 1851 at the Faculty of Philosophy of Academia Mihăileană of Iași. Also, at the School of Bridges and Roads in Bucharest, elements of mechanics applied to usual machines were taught since 1850. The lecturers of these courses were I. Constantinescu in 1851, C. Zeuceanu during 1869–1870 and 1873–1877, and E. Angelescu during 1870–1873 (Andonie 1965; Atanasiu 2017). During 1875–1879, C. Olănescu, graduate of the School of Art and Manufactures in Paris taught elementary mechanics, kinematics, the strength of materials and hydraulics. During 1881–1902, C. Mănescu—licensed in mathematics at the Faculty of Sciences in Iași, and of the School of Bridges and Roads in Paris—taught a course on mechanics applied to the strength of materials and stability of buildings. This course was printed and lithographed in 1893 and 1894 (Mănescu 1893, 1894) and was subsequently taught during 1902–1915 by H. Schlawe, graduate of the School of Civil Engineering at Ghent University in Belgium. This course (Schlawe 1913) also contained elements of theory of elasticity and new findings of European research in this field during 1893–1913. In 1886, at the National School of Bridges and Roads, professor A. Saligny (Atanasiu 2017) founded the Laboratory of Chemistry as the first technological laboratory in Romania. This laboratory developed during 1886–1940 by acquiring new equipment for chemical analyses, and testing machines. A Werder testing machine with a maximum force of 1000 kN was bought from Germany in 1888. It was, at that time, the state-of-the-art in the field of mechanical testing, and it was used to test steel profiles intended for the structure of Cernavodă Bridge over the Danube River (1890–1895), as well as materials used to build docks in Constanța harbour and other significant national works. In 1923, professor C.C. Teodorescu founded the Laboratory of Strength of Materials at the Polytechnic School in Timișoara. Apart from the testing machines bought from abroad, it is important to note that all of the other machines were designed and manufactured locally.

The mechanics of deformable solids further developed due to G.E. Filipescu, professor at National School of Bridges and Roads in Bucharest, who wrote and published in 1935 a course under the title *Statica construcțiilor și rezistența materialelor* in three volumes, further re-printed in a single volume in 1940 (1940). This work presents the main problems of strength of materials in an original way, using vectors. The high-level scientific content, the mathematical and rigorous level in which the fundamental notions are presented yielded highly appreciative reviews from different European scientific figures, reviews included in the preface of the 1940 edition of the book. G.E. Filipescu carried out research and had new contributions to the theory of elasticity regarding buckling of elastic bars, lateral buckling, bending and torsion of electric car railway tracks, and hypotheses of strength of materials. He proposed an original method to study statically indeterminate bent beams using the principle of virtual displacement. This was the first Romanian contribution to strength of materials, and was called the method of indeterminate coefficients or the Filipescu method. The research carried out by C.C. Teodorescu—professor and Rector of the Polytechnic Schools in Bucharest and Timișoara (Andonie 1965; Popescu 2011; Teodorescu 1945)—focused on two main fields: material testing and calculus, and testing of welded joints. He was the first to apply statistical methods, based on the theory of probability, to the processing of mechanical testing results, and he proposed a method to compare two characteristic limits of materials subject to mechanical tests. The first doctoral theses of Romanian researchers in the theory of elasticity (Andonie 1965) were prepared by R. Müller from Rupea, in 1908, and P. Boroș in 1919, at Technische Hochschule in Berlin. The first thesis defended in Romania in the field of mechanics of deformable solids was titled *La résolution des systemes hypérstatiques par deux méthodes recentes (critique et extension des methodes Filipescu et Cross)*, and it was presented in 1938 by Associate professor C. Mateescu. In 1939, Ș. Nădășan defended his thesis titled *Rezistența dinamică a fontei* at the Polytechnic School in Timișoara. Other contributions to the mechanics of deformable solids were brought by V. Vâlcovici, A. Beleș, M. Hangan, P. Mazilu (Andonie 1965), who proposed new methods for strength calculations in civil and industrial structures. C. Vâlcovici determined the frontier between stability and non-stability in the case of elastic buckling. A. Beleș, together with M. Soare, published the monograph titled *Paraboloidul eliptic și hiperbolic în construcții*, which was the first one on such a subject in the world scientific community. M. Hangan established new methods of strength calculation for beams, plates and tanks made of reinforced concrete. Romanian researchers were present when the International Association for Materials Testing was established in 1928, having N. Vasilescu Karpen—Rector of the Polytechnic School in Bucharest—as vice-president.

After the Second World War, many changes happened in the technical higher education system due to the reform of 1948 and to the new policy of industrialisation in Romania. The number of institutes, faculties, faculty members and students increased, and departments of strength of materials were set up. The activity of the Romanian Academy has been extended and the Research Base in Timișoara has been established. The Institute of Applied Mechanics was established in 1948, and transformed in 1965 in the Institute of Fluid Mechanics, led by E. Carafoli. In addition, the Centre for Solid Mechanics—headed by Ș. Bălan—was established. These institutes have been involved in approaching new directions of research in mechanics, with applications in machine building, hydro-technical and aero-technical constructions, fundamental and applied research. Under the aegis of the institute, the journal titled *Studii și cercetări de mecanică aplicată* started to be printed both in Romanian, and in French. In 1955, the Editura Tehnică published a book of applications in strength of materials, under the coordination of G. Buzdugan, as well as the course on strength of materials by the same author (Buzdugan 1956). This course has been considered a fundamental work in this field for many years, and professor Buzdugan represented a landmark in solid mechanics (Banabic 2013) for over 35 years. After several years, many courses were published, written by different professors from all universities in Romania. In this period, the research in the field of theory of elasticity boosted due to numerous applications proposed in different technical fields. For example, professor A. Șesan from the Polytechnic Institute in Iași demonstrated that the principle of Menabrea can be applied to the elastic-plastic or fully plastic equilibrium of structures (Andonie 1965). Some of the research carried out was based on the planar or three dimensional problem of elasticity to obtain a general solution, while other research approached problems of thermo-elasticity or elasto-dynamics. In this field, several works may be cited, such as *Teoria elasticității* by M. Haimovici, *Teoria elasticității și introducere în mecanica solidelor deformabile* by P.P. Teodorescu, *Statica și dinamica structurilor elastice anizotrope și heterogene* by L. Librescu, *Elasticitate liniară. Introducere matematică în statica solidului elastic* by L. Solomon, *Mecanica mediilor deformabile* by M. Mișicu, *Teoria aeroelasticității* by A. Petre, *Termoelasticitate* by I. Grindei, *Rezistența materialelor și teoria elasticității* by C. Bia, V. Ille, and M. Soare.

W. Kecs and D.Muchinescu worked in the field of applications to the theory of distributions to solve some problems of theory of elasticity. Other important contributions were provided by Teodorescu (2009b). In other works by A. Gheorghiu, D. Mateescu, C. Avram, P. Mazilu, H. Sandi, A. Pârvu, D. Stan, E. Soos, M. Mihăilescu, V. Visarion, (Andonie 1965), technical aspects prevail. During 1950–1965, laboratories from universities and research institutes were provided with equipment for stress analysis in structures, according to the concerns of the international researchers and the needs of the economy. Material testing remained only a part of the experimental work. In 1950 N. Iosipescu initiated the first Romanian experiments in photoelasticity (Iosipescu 1958) for the determination of stress state in loaded structures. He facilitated this course at the Department of Mechanics of the Faculty of Mathematics within the University in Bucharest, where he established a laboratory of research in photoelasticity. Iosipescu can also be considered a pioneer of the moiré method for stress and strain determination in planar plates. He proposed the scientific base of pure shear testing of a double split beam non-symmetrically loaded, for which he obtained patent no. 42082. His method was also patented in USA, Germany, Switzerland, and Austria, and published in the Journal of Materials. Both the Romanian standard STAS 7926-67, and the American standard ASTM D-5379-93 for pure shear testing of composite materials were established based on the Iosipescu's research and his testing method already known all over the world as the Iosipescu method for pure shear testing.

Gradually, strain gauges for static and dynamic testing were introduced in Romania in different laboratories. At the Railway Research Institute, a strain gauge laboratory was established in 1958, consisting of two laboratory wagons for experimental measurements in a dynamic regime. A hydraulic stand for testing locomotives and railway cars was introduced together with an experimental ring for testing rolling stock. Books and papers on strain gauges were published by research groups led by G. Buzdugan and D.R. Mocanu (Theocaris et al. 1966, Atanasiu et al. 1982).

At this time, mostly the laboratories of technical universities used optical methods for the analysis of stress and strain state (photoelasticity, moiré and holography) in machine structures and civil engineering, and in agricultural and industrial structures. Applied research in the mechanics of deformable solids was deeply involved in solving industrial problems, using mainly calculation methodologies experimentally verified using either dynamic or static strain gauge measurements and photoelasticity measurements of the stress state in supporting structures (mechanical equipment of power plants, locomotives, railway cars, elevators, process equipment, precompressed concrete beams, pressurized pipes, tanks, metallurgical or agricultural equipment).

New laboratories for teaching and research were established in technical universities in Bucharest, Timișoara, Cluj, Iași, and Brașov. Modern facilities for scientific investigations in the mechanics of deformable solids were developed in the laboratories of research institutes. During 1970–1989, a rapid development is noticed in research using numerical methods (and especially the finite element method) to obtain the stress and strain states in structures. Several books presenting this method appeared and thousands of papers were published or presented at scientific symposia or conferences. It is worth underlying the contributions of Mangeron (1980), Voinea et al. (1989).

Theoretical and experimental activities in the mechanics of deformable solids have developed due either to the schools established up to 1948 or to new ones created within different universities, and activities of professional associations. The School of mechanics of deformable solids within the Polytechnic University of Bucharest, with deep roots and great tradition, had a very solid base and continuity (Andonie 1965; Atanasiu 2017). The schools established after the Second World War in other various universities drawn their research efforts to solve industrial problems in their area.

The scientific activity in the field of mechanics of deformable solids has been reflected in the organization and participation of Romanian researchers to international conferences. Some of such conferences were organized by the Division of Technical Sciences within the Romanian Academy and by the Romanian Association of Experimental Stress Analysis. The Department of Strength of Materials at the Polytechnic Institute in Bucharest organized several scientific events: the Symposium on Experimental Techniques in Applied Mechanics (1972), the Euromech Colloquim on Dynamics of Machine Foundations (1973, 1985 and 1994).

Great transformations are noticed after 1989 in the technical higher education. New specialisations, faculties and state or private universities appeared; the three-cycle Bologna system was adopted. The fundamental research, especially in the institutes of the Romanian Academy, intensified. The scientific research diversified, including new directions of research such as fracture mechanics, structural integrity, damage modelling and simulation, durability of structures subject to variable loadings. A new direction of research appeared due to the emergence and extensive use of new metallic, plastic or composite materials: mechanical testing for the determination of mechanical characteristics and response under loads. The exceptional development of computers allowed the researchers to extensively use the finite element method for the static and dynamic analysis of the stress state in structures and for stability analyses.

The Department of Strength of Materials at the Polytechnic University of Bucharest, the University of Tarbes in France, the University of Patras in Greece, and, further, the University of Porto in Portugal organize every two years an international conference on structural analysis of advanced materials. The Romanian Association of Experimental Stress Analysis and Materials Testing (ARTENS) is currently a member of the Danubia-Adria Society on Experimental Methods, society having as members scientific associations from 11 European countries. Departments of mechanical engineering at the main universities in Romania, professional associations (for experimental stress analysis, fracture mechanics, theoretical and applied mechanics) and research institutes of the Romanian Academy organize every two years international conferences on different aspects and trends of the mechanics of deformable solids.

In 1997, the Technical Sciences Academy of Romania is established, including a Section of Technical Mechanics, which organizes an annual international conference, and is the editor of the *Journal of Engineering Sciences and Innovation.*

3.2 Mechanical Vibrations

Valentin CEAUȘU, Costică ATANASIU

The field of mechanical vibrations studies the oscillations of elastic systems, and is considered a part of mechanics. Oscillatory motion can be otherwise encountered in all chapters of physics. The theoretical and experimental study of vibrations is needed to evaluate their negative effects on human beings, operation of machinery, constructions and foundations. Moreover, vibrations are used in designing devices such as vibrating mills or sieves, vibrating conveyors, vibro-impact machines, etc. The first vibration-related concepts were developed by Thales of Miletus and Pythagoras of the Ionian school of philosophy (Dimarogonas 1990; Dimarogonas and Haddard 1992). The modern study of vibrations begins at the end of the 19th century, and is related to the rapid progress of technology in sea navigation, aviation, and high speed rotating machines (Timoshenko 1928).

In Romania, the first paper in the field was *Oscilarea vagoanelor în timpul mersului,* prepared by Gogu Constantinescu and published in *Buletinul Societății Politehnice* in 1905. During the first half of the 20th century, the study of vibrations could be found (Buzdugan 2011) exclusively in books written by professors at the Polytechnic School in București: *Statica construcțiilor și rezistența materialelor* by Gh. Em. Filipescu (1940), *Probleme de oscilații* by Al Stoenescu (1939), and *Curs de rezistența materialelor* by Teodorescu (1945). In addition, an important contribution is the work titled *Theory of Sonicity. Treatise of Power Transmission by Vibrations* (*Teoria sonicității. Tratat despre transmisiunea puterei prin vibrațiuni)* (vol. I) by Gogu Constantinescu (1922). This book was first printed in English in 1918, then in Romanian in 1922. A second edition was printed in 1985 by Editura Academiei Române. The article *Cutremurul și construcțiile* published by A. A. Beleș in 1941 in *Analele Academiei Române* boosted the theoretical and experimental research in the field of anti-seismic design and analysis.

In technical universities, the study of vibrations was introduced in 1948 as part of two fundamental disciplines: the vibrations of discrete systems with one or multiple degrees of freedom within the discipline of Mechanics, and the concepts of continuum media within the discipline of Strength of Materials. At the recommendation of Romanian Academy members Gh. Buzdugan and R. Voinea, a standalone course on Mechanical Vibrations was introduced in 1976 in the curriculum of all engineering programs having a mechanical profile. Applied courses of vibrations and dynamics were also added to various engineering programs, such as machine tools, automotive, railway, naval systems, construction machinery and technological equipment. Among the textbooks used one can mention those coordinated by Bratu (2002), Ispas (2007), and Chiriacescu (1982). Individually or in collaboration, Gh. Buzdugan, member of the Romanian Academy, published numerous scientific works dedicated to mechanical vibrations in the field of machine manufacturing (Buzdugan et al. 1961, 1975, 1986; Buzdugan 1980, 1968). He also coordinated the translation into Romanian of *Shock and Vibration Handbook* edited by Harris and Crede (1961). A. Petre published remarkable works in the field of fluid-structure interaction, such as *Teoria aeroelasticității* (Petre 1966, 1973). The book titled *Metode dinamice pentru identificarea sistemelor mecanice* (Radeș 1975) by M. Radeș is considered the first monograph on its subject. M. Radeș is also co-author and editor of *Encyclopedia of Vibration* (Encyclopedia of Vibration 2002). Prof. Gh. Silaș at the Polytechnic University of Timișoara covered the area of nonlinear vibrations, especially impact vibrations (Silaș 1968; Silaș and Brîndeu 1968). D. Mangeron, professor at the Polytechnic University of Iași published *Mecanica vibrațiilor sistemelor rigide* (Mangeron and Irimiciuc 1981), and *Fundamentele mecanicii* (Gaboș et al. 1961). A. Ripianu at the Technical University of Cluj published works on crankshaft vibrations such as *Mișcările vibratorii ale arborilor drepți și cotiți* (Ripianu 1973) and *Calculul dinamic și de rezistență al arborilor drepți și cotiți* (Ripianu and Crăciun 1985). Remarkable scientific works in the field of vibrations and acoustics were also authored by other mathematicians, physicists or engineers: Sireteanu et al. (1981), Magheți and Savu (2007), Dinca and Teodosiu (1973).

After 1990 an increase can be seen in the number of research topics, as well as improvements in the equipment available to sound and vibration labs (Silaș 1968). The research in the field of noise and vibrations is currently addressing concerns regarding their negative impact on human beings, machines, equipment and structures.

3.3 Theory of Plasticity

Dorel BANABIC

The theory of plasticity deals with the study of the behaviour of materials submitted to equivalent stress above the yield stress. The application of the plasticity theory in the study of deformation through pressing allows for an analytical approach to technological problems and a scientific examination of the phenomena which occur during these processes. The development of this theory was stimulated by the need for mathematical modelling of certain industrial processes (lamination, forging, extrusion, drawing, etc.).

The first studies on plasticity in Romania were initiated after the First World War by researchers in the field of elasticity and strength of materials (Andonie 1965). The applications of plasticity calculus which occurred during this period were mostly in the field of building and bridge structures. Of those who began their work before 1945, there are several names worth mentioning. C. C. Teodorescu, professor of Material Strength at the Polytechnic school of Timișoara and then at its Bucharest counterpart, contributed significantly to the field of material testing (Teodorescu 1927). He was one of the first researchers worldwide to use statistical methods to process data obtained through mechanical trials (Teodorescu 1934). Furthermore, he helped advance the calculus of the strength of railway tracks placed on elasto-plastic bearings (Teodorescu 1968). Another professor in the field of construction, Mihail Hangan, contributed to determining the order of appearance of plastic articulations in concrete structures, as well as to the calculus of hyperstatic structures in the science of plasticity (Hangan 1959). A special contribution on behalf of the Romanian school of construction came from Romanian Academy Member Ștefan Bălan, who, in collaboration with S. Răutu and V. Petcu, introduced a new method for analysing structures, one which was completely new to the world, called *chromoplasticity* (Bălan et al. 1963).

The founder of the theory of plasticity in Romania is Nicolae Cristescu. He was the one to conduct the first systematic studies in the field of the plasticity theory as part of his doctoral thesis called *Asupra unor probleme dinamice de teoria plasticității* (*On certain Dynamic Issues of the Theory of Plasticity*) (Cristescu 1955), which he defended at the University of Bucharest in 1955 (having Gr. Moisil as a thesis supervisor). In the same year, he introduced the first course in the Theory of Plasticity ever held at a Romanian university. He subsequently went more in depth into the field and published his results in the book titled *Probleme dinamice* *de teoria plasticității* (*Dynamic Issues of the Theory of Plasticity*) (Cristescu 1958). The results of personal and international research were published in 1967 in the book called *Dynamic plasticity* (Cristescu 1967), which was translated into Japanese in 1970, being the first book of exact sciences written by a Romanian ever published in that language. He was invited to hold conferences and courses in the field at numerous universities in Poland, England, France, Germany, and especially the USA. From 1970 onwards, he channeled his research towards the field of rheology and rock mechanics, publishing the results of his work in Romanian (*Vîscoplasticitate* (Cristescu and Suliciu 1976), *Mecanica rocilor* (Cristescu 1990)) and English (*Viscoplasticity* (Cristescu and Suliciu 1982), *Rock Rheology* (Cristescu 1989)), respectively. Furthermore, in 1970-80, he also tackled the technological applications of the plasticity theory, especially those of viscoplasticity, in technological processes such as wire drawing, pipe extrusion and drawing. The results of his research were published in numerous articles and summarised in the book titled *Teoria plasticității cu aplicații la prelucrarea metalelor* (*Theory of Plasticity and Its Applications in the Processing of Metals*), published together with his collaborator, S. Cleja-Țigoiu (Cleja-Ţigoiu and Cristescu 1985). The professional prestige earned due to his many publications (articles in specialised magazines, books) and his role as a pioneer in certain fields of the plasticity theory (the dynamic of plasticity, rock mechanics, viscoplasticity) made it possible for him to found the *International Journal of Plasticity*, as the initiator and first editor-in-chief if this prestigious magazine. In 1990–1992, he was the rector of the University of Bucharest, the first one to be elected democratically after the revolution of 1989. He subsequently worked at the University of Florida until his retirement, after which he returned to Romania. Professor Cristescu created the first school for the theory of plasticity in Romania and one of the most well-known and prestigious schools in Europe. This is the school which trained many mathematician-mechanician researchers, such as: S. Cleja-Țigoiu, I. Suliciu, C. Făciu, O. Cazacu, M. Gologanu and many others scattered all over the world (USA, France, Germany).

Another founder of a school in the field of plasticity in Romania was Professor Cristian Teodosiu, graduate of both the Bucharest Institute of Construction (1958) and of the University of Bucharest (the Faculty of Mathematics) (1960). He defended his doctoral thesis called *Contribuții la teoria macroscopică a dislocațiilor și tensiunilor inițiale* (*Contributions to the Macroscopic Theory of Initial Dislocations and Tensions*) at the Romanian Academy Institute of Mathematics under the supervision of Professor Gr. Moisil. His double specialisation—in mathematics and engineering—allowed him to tackle engineering issues regarding microscopic modelling using advanced mathematical means. Up until his leaving Romania, he worked as a researcher at the Romanian Academy Institute of Solid Mechanics and was the Director of Research of the Bucharest Institute of Physics and Materials Technology. From 1985 to 2002, he worked at the National Polytechnic Institute of Grenoble and the Paris 13 University, where he was the coordinator of the Laboratory for Mechanical and Thermodynamic Properties of Materials (LMTPM). He elaborated a hammer hardening model highly efficient in predicting the behaviour of sheet metal during deformation processes. He supervised numerous doctoral theses and postdoctoral internships during his active time both in Romania and at the universities of Grenoble and Paris. During the last part of his activity (2002–2011), he was coordinator of the *Volume-CAD System Research* laboratory at the Riken Institute in Japan. He was the editor of an excellent book called *Large Plastic Deformation of Crystalline Aggregates* (Teodosiu 1997), which contains the papers presented at a symposium organised under the auspices of the International Centre for Mechanical Sciences of Udine, Italy.

Petrișor Mazilu made significant contributions in the field of constitutive equations and variational principles in plasticity (Mazilu 1982). He worked at various universities in Germany (Bochum and Darmstadt) in the 1980s, where he developed models for the description of the induced anisotropy of pre-deformed materials. He introduced the hypothesis of translating the centre of the isotropic surface (ICT) in order to describe the significant transformation of the shape of the isotropic yield surface of an undeformed material into an anisotropic one after deformation.

Professor Mircea Predeleanu was trained and worked in Romania, then emigrated to France. He defended his doctoral thesis called *Contribuții la studiul matematic al unei clase de corpuri cu proprietăți reologice* (*Contributions to the Mathematical Study of a Class of Bodies with Rheological Properties*) in 1961 under Romanian Academy Member Gr. Moisil. He contributed to the field of rheology and that of creep constitutive equations. Subsequently, after emigrating to France, he directed his research efforts towards the field of fault prediction in manufacturing processes. In 1987, he initiated a series of conferences in the field of numerical methods for fault prediction in the processing of materials (Predeleanu 1987). In 1985–1992, he was the Director of the Laboratory of Mechanics and Technology of the Paris-Saclay Superior School of Cachan.

Sanda Cleja-Țigoiu was a collaborator of Professor Nicolae Cristescu, as she continued the Plasticity Theory course. She specialised in the theory of plasticity at the State University of Moscow, Russia, where she conducted her doctoral studies. Her contributions are related to the irreversible behaviour of elastoplastic materials with structurally non-homogeneous elements such as dislocations and the anisotropic deterioration of elastoplastic materials with structural faults.

Dr. Ioan Suliciu was one of the first collaborators of Professor Nicolae Cristescu, together with whom he published articles and monographs in the field of viscoplasticity (Cristescu and Suliciu 1976, 1982). It was at the school of plasticity of the University of Bucharest that Cristian Făciu was trained as well; he first collaborated with I. Suliciu in research regarding viscoplasticity and subsequently tackled issues regarding the modelling of the Portevin-Le Chatelier effect.

Oana Cazacu, currently a Professor at the University of Florida USA, comes from the same school of plasticity of the University of Bucharest. After her doctoral studies and her habilitation at the University of Lille, France, she continued her research activities at the University of Florida. This is where, together with Nicolae Cristescu, she tackled issues regarding rock mechanics and, in the early 2000s, developed a set of plasticity criteria for original anisotropic media based on the expansion of the Drucker criterion. She edited several books in the field of multiscale modelling of materials, such as: *Multiscale Modeling of Heterogeneous Material* (Cazacu 2008), *Linking scales in computation: from microscale to macroscopic properties* (Cazacu 2012) etc. Mihai Gologanu, graduate of the University of Bucharest, completed his doctoral studies at the Pierre-et-Marie-Curie University of Paris, France. He expanded the plasticity model with gaps by proposing an ellipsoidal shape for them instead of the spherical one and the coupling of this model with non-square models of anisotropic plasticity.

Relative recently (after 1995), a research group was created in the field of the plasticity behaviour of sheet metal at the Technical University of Cluj-Napoca, with Professor Dorel Banabic as its coordinator. In the early 2000s, the group developed a research laboratory for the analysis of mechanical behaviour and of sheet metal deformation. The main results obtained by the group were in the field of modelling and the experimental determination of borderline deformation, anisotropic-behaviour modelling, and multiscale modelling of sheet metal. The model of material developed by the members of the CERTETA group of the Technical University of Cluj-Napoca was implemented in the AutoForm commercial programme with finite elements. A substantial activity within the CERTETA research group was conducted by Dr. Dan Sorin Comșa, Dr. Mihai Gologanu, Dr. Tudor Bălan, Dr. Lucian Lăzărescu. The results obtained by the group were published in several books published by international publishing houses, such as: *Formability of Metallic Materials* (Banabic et al. 2000), *Sheet Metal Forming Processes* (Banabic 2010) (translated into Chinese (Banabic 2015), the first engineering book written by a Romanian to be translated into that language), *Multiscale Modelling of Sheet Metal Forming* (Banabic 2016). Professor Tudor Bălan, graduate of the Technical University of Cluj-Napoca, completed his doctoral thesis at CEMEF, École des Mines de Paris in the field of forging process optimisation and went on to work at the University of Metz, France. This is where he tackled topics regarding anisotropic-behaviour modelling and the simulation of the processes of plastic deformation of sheet metal.

4 History of Contact Mechanics

Mircea PASCOVICI

4.1 The Evolution of the Scientific Analysis of Mobile-Contact Mechanics

The foundations of buildings and machine design were laid along the years mainly through experiments which, at first, were putting under question the problem of “whether or not will it hold”, then were intended for phenomenological analyses or for the verification of theories and, more recently, for the validation of models. The components of mechanisms and machines were initially analyzed from a rigidity point of view as more or less rigid (Haton de la Goupilliere 1864). About 200 years ago, starting with Young who, in 1807, defined the elasticity module, and continuing with Navier, Barre de Saint-Venant, Poisson, Cauchy, Maxwell, etc., the foundations of the theory of elasticity and of that of the strength of materials were established. It was still in the first half of the 19th century when the mechanics of viscous fluids was established, due to the equations of Navier-Stokes (Dowson 1998).

These solid grounds provided the prerequisites for the scientific analysis of the friction processes which appear at the interface of the mobile contacts of machines and other such devices. The prime goal has been the drastic reduction of friction and wear, the main solutions being lubricated or rolling contacts. One might say that a triad of pursuits has long been identified in the problematics of mobile contacts, namely *friction-wear-lubrication.* In 1966, the British government introduced the term *tribology* to refer to the set of pursuits comprised by the above-mentioned triad (Wang and Chung 2013), term which then spread worldwide.

The friction processes which occur at the interface of lubricated kinematic couplings could only be tackled thoroughly after the publication of the revolutionary articles authored by Heinrich Hertz (1883) and Osborne Reynolds (1886). In 1881–1883, H. Hertz determined the pressure distribution for non-compliant, punctual (elliptic), stationary, unlubricated contacts in an elastic regime (Hertz 1882). His relation for the calculation of maximum pressure became the calculation basis for bearings, gears, cams, and a plethora of other applications. In 1886, O. Reynolds determined the distribution of pressures in the lubricated gap between conformal contacts with rigid solid surfaces (sliding bearings) by resorting to a brilliant simplification of the Navier-Stokes equations (Reynolds 1886). The differential equation that bears his name, which is extremely flexible/adaptable, is used in its various forms for the determination of the supporting capacity for dozens of types of lubrication problems (Reynolds 1886).

For a detailed account of the personalities who contributed to the development of tribology, one recommends consulting D. Dowson's book *History of Tribology* (Dowson 1998).

4.2 Scientific Research on the Topic of Contact Mechanics In Romania

The first systematic scientific studies in Romania in the field of friction processes on the interface of mobile mechanical contacts appeared in 1949, with the creation of the Institute of Metallurgy and Applied Mechanics of the Academy of the Romanian People's Republic, which later became the "Traian Vuia" Institute of Applied Mechanics (IMA, Institutul de Mecanică Aplicată). Subsequently, the institute was divided into the Institute of Fluid Mechanics (1965) and the Centre for Solid Mechanics (CMS, Centrul de Mecanica Solidelor). After that, names and pursuits changed at an accelerated pace, while the research on contact mechanics in successor institutions, became increasingly scarce and nearly extinct.

The notable figures in the field of the mechanics of lubricated contacts at the IMA were professors Nicolae Tipei (1913–1999) and Virgiliu Niculae Constantinescu (1931–2010). Both of them can be considered giants of the Romanian and the international fields of lubrication. Contact mechanics research at the CMS was led by Professor Dan Pavelescu, then by Ivan Iliuc.

After 1950, significant studies in contact mechanics were conducted at the Bucharest Polytechnic Institute under the leadership of Professor Gheorghe Manea, mainly in the field of sliding radial bearings, and at the "Gh. Asachi" Polytechnic Institute of Iași, ~~led~~ by Professor Niculae Popinceanu, primarily in the field of bearings.

Subsequently, notable studies in contact mechanics were developed at the Ștefan cel Mare University of Suceava, under the leadership of Professor Emanuel Diaconescu, as well as in the field of elasto-hydrodynamic (EHD) lubrication, within Dunărea de Jos University of Galați, led by Professor Ion Crudu, and at the Technical University of Cluj-Napoca, led by Professor Dorina Mătieșan Jichișan.

4.3 The Key Figures of Contact Mechanics in Romania

Chronologically, the key figure of lubrified-contact mechanics was Niculae Tipei, corresponding member of the Romanian Academy since 1963. His activity in Romania is mainly illustrated by the book published by the Publishing House of the Romanian Academy in 1957, with him as the sole author (Tipei 1957), titled *Hidro-aerodinamica lubrificației* (*Hydro-Aerodynamics of Lubrication*), which was translated into English in 1962 by Stanford University as *Theory of Lubrication: with Application to Liquid and Gas Film Lubrication* (Tipei 1962).

The work of professor N. Tipei at General Motors, much more thematically diverse and highly interesting, was the object of many published articles and research works which are yet inaccessible, as they are the property of General Motors. In 1980, he was awarded the Mayo D. Hersey Prize by the American Society of Mechanical Engineers (ASME).

Another particularly important representative of lubricated-contact mechanics was Professor Virgiliu Niculae Constantinescu, member of the Romanian Academy since 1991, and ~~its~~ president from 1994 to 1998. He is the *de facto* father of gas lubrication in Romania. He worked at the IMA and the Bucharest Polytechnic Institute, which he led from the position of rector between 1990 and 1992. In the "Bible" of *hydrodynamic lubrication* written by Pinkus and Sternlicht (1961), published in 1961, he is already cited (at the age of 25!) with an article published in Romanian in 1956 within *Studii și Cercetări de Mecanică Aplicată* (*Studies in Applied Mechanics*). In 1963, the Publishing House of the Romanian Academy issues the monograph titled *Lubrificația cu gaze* (*Gas Lubrication*) (Constantinescu 1963), translated into Russian in 1968 and into English in 1969 (Constantinescu 1969). In

1965, his monograph called *Teoria lubrificației în regim turbulent* (*Theory of Lubrication in a Turbulent Regime*) (Constantinescu 1965) was published, then translated into English in 1968 (Constantinescu 1968). In this monograph, V. N. Constantinescu proposes a new method for solving lubrication problems in a turbulent regime, namely that of the *mixing length*, still in use today. The article *On Turbulent Lubrication*, published in 1959 in the *Proceedings of the Institution of Mechanical Engineers* (Constantinescu 1959), which contains the basic ideas in the above-mentioned monograph, is his most cited work. In 1968, his widely used book *Aplicațiile industriale ale lagărelor cu aer* (*Industrial Applications of Air Bearings*) was published by the Publishing House of the Romanian Academy. In 1980, Editura Tehnică (the Technical Publishing House) published his monograph *Lagăre cu alunecare* (Constantinescu et al. 1980), written in collaboration with others, which was translated into English as *Sliding Bearings* (1985) in 1985 and published by the Allerton Publishing House in the USA. He conducted unparalleled research and training work at international level, especially in collaboration with institutions in the USA and France, tackling almost all the problems of lubricated-contact mechanics.

Professor Gheorghe Manea (1904–1978), corresponding member of the Romanian Academy from 1963, conducted his activity at the Bucharest Polytechnic Institute. Educated at the Polytechnic School of Berlin-Charlottenburg, having doctored in the hydrodynamics of turbine rotors in 1932, under the supervision of famous Professor H. Föttinger, he is the inventor of hydrodynamic couplings.

He introduced and promoted the basis of the design of fluid-friction bearings in Romania. The treatise titled *Organe de mașini* (*Machine Organs*) (Manea 1970), published in 1970 by Editura Tehnică, laid the foundations of modern teaching with regards to this subject worldwide. His training and research work in the field of lubrication and gears was particularly significant due to its rigor and its development of experimental research. Professor Gheorghe Manea supervised four doctoral theses up to their completion, namely those of Teodor Mladinescu, Mustafa Akkurt, Mihai Gafițanu, and Mircea D. Pascovici. The latter three became doctoral supervisors themselves in the same field of machine design and tribology. Professor M. Akkurt worked at the Bucharest Polytechnic Institute until 1969 and then, at the Technical University of Istanbul, Professor M. Gafițanu was active at the "Gh. Asachi" Technical University of Iași, and Professor M. D. Pascovici at the University Politehnica of Bucharest.

The "Gh. Asachi" Polytechnic Institute of Iași hosted the activities of Professor Niculai G. Popinceanu (1913–1999), who founded a school of rolling-contact mechanics with applications for bearings, a school of the highest competence in Romania. He contributed to the training of many specialists in the field, among which Mihai Gafițanu, Emanuel Diaconescu, Spiridon Crețu, and more. Together with the above, he published the monograph *Probleme fundamentale ale contactului cu rostogolire* (*Fundamental Issues of Rolling Contact*) (Popinceanu et al. 1985), issued by Editura Tehnică in 1985.

It was the role of Professor Dan Pavelescu (1922–2013), who worked at the Centre for Solid Mechanics (CMS) and at the University Politehnica of Bucharest (UPB), to coagulate the tribological community in Romania by founding the National

Tribology Committee in 1977 and, in 1990, the Romanian Tribology Association (ART, Asociația Română de Tribologie), affiliated to the International Tribology Council, created in 1973, as well as to the Balkan Tribology Association, founded in 1994, with ART as a founding member.

A comprehensive account of the activities and figures in the field of contact mechanics (called *tribology* in Romania as well after 1977) between 1950-2003 is found in the work of Professor Dan Pavelescu (2003).

5 History of Fluid Mechanics and Hydraulic Equipment

5.1 History of Fluid Mechanics

Sebastian MUNTEAN

Ladislau Vekas

The study of fluid mechanics dates back to the time of Ancient Greece, when Archimedes was pursuing the study of fluid statics (Archimedes' principle). This was continued by the research conducted by Leonardo da Vinci (observations and experiments), Galileo Galilei (who indirectly influenced experimental hydraulics and revised the Aristotelian concept of vacuum), Blaise Pascal (who clarified the principles of the barometer, the hydraulic press, and pressure transmission, as well as certain elements of hydrostatics), Isaac Newton (viscosity), Henri de Pitot (who invented a device to measure water velocity—the Pitot tube). The development of hydraulics was carried forward by Daniel Bernoulli with his mathematical description of fluid dynamics in his work *Hydrodynamica* (1738), where he enunciated, among other things, the famous equation that bears his name. Inviscid fluids were studied by mathematicians such as Leonhard Euler, who explained the role of pressure in fluids, formulated the basic equations of motion, introduced the concept of cavitation and the principles of the centrifugal machine, D'Alembert, Antoine Chézy (1718–1798), Lagrange, Giovanni Baptista Venturi (1746–1822), who performed tests on tapered reducers, Laplace, Claude-Louis Navier (1785–1836), Poisson. On the other hand, viscous fluids were tackled by a plethora of engineers, such as Poiseuille or Gotthilf Heinrich Ludwig Hagen. A more detailed mathematical study on fluids was conducted by Claude-Louis Navier and George Gabriel Stokes, who established the famous Navier–Stokes equations, while borderline conditions were investigated by Ludwig Prandtl. Numerous researchers, such as Osborne Reynolds, Andrey Kolmogorov, Geoffrey Ingram Taylor, etc., facilitated the understanding of the concepts of viscosity and turbulence.

Research in the field of fluid mechanics is closely linked to the development of Romanian higher education. Chronologically, the first paper in this new field for Romanian education was elaborated by **Victor Vâlcovici** in 1913, as it constituted his doctoral thesis called *Mişcări fluide discontinue cu două linii libere* (*Discontinuous Fluid Motions with Two Free Dimensions*), which he defended in Göttingen, Germany. The work was in accordance with the scientific pursuits of the time, so that it was appreciated and frequently quoted in writings about these phenomena. Victor Vâlcovici is considered to be the creator of Romanian theoretical hydrodynamics and aerodynamics.

Professor **Dionisie Germani** pursued specialised education in Belgium, Germany, Great Britain, and France and obtained his engineering degree from the École Supérieure d'*É* électricité of Paris (1919) and his title of Doctor of Science from Sorbonne. In his capacity as director of the Hydraulics and Hydraulic Machines Department (1920–1938) and then dean of the Faculty of Construction of the Polytechnic school (1938–1944), Professor Germani conducted intense teaching and research activities in the field of theoretical and applied hydraulics, hydrotechnical plants, and water supplying in urban settlements; he authored the first treaty on theoretical and applied hydraulics (*Hidraulică teoretică şi aplicată*) ever published in Romania (consisting of 4 volumes which appeared in 1937–1938) (Germani 1942). He made remarkable contributions to the theory of similarity and to the development of laboratory procedures for the testing and studying of hydrodynamic equipment and hydraulic plants. Germani supported young Romanian researchers who had returned from studying abroad and contributed in a decisive way to the forming of the school of fluid mechanics of the University Politehnica of Bucharest. Future professors Dorin Pavel, Dumitru Dumitrescu, Elie Carafoli, Nicolae Tipei enjoyed the assistance and guidance of Dionisie Germani. The first Laboratory of Hydraulics of the University Politehnica was created in 1929 by Professor Germani and Dorin Pavel, who at the time was a young teacher, graduate of the famous E.T.H. Zürich university (1923), where he was awarded the title of Doctor under the mentoring of Prof. Franz Prašil, while Prof. Ludwig Stodola was the head of the examining committee (1925).

After obtaining his engineering diploma and degrees in mathematics, letters, and philosophy, **Dumitru Dumitrescu** enhanced his professional training first at the Superior School of Electricity of Paris, as a student of the famous Professor Janet, then at the School of Aeronautics. He carried out his preparation for his doctoral thesis at the University of Göttingen under the supervision of Prof. Ludwig Prandtl. His doctoral thesis called *Curgerea unei bule de aer într-un tub vertical* (*The Flow of an Air Bubble in a Vertical Tube*), defended in 1942, soon became a classic work, quoted in prestigious treatises and manuals in various countries. He returned to Romania after 1940 and worked as an engineer at the Airplane Factory in Braşov, and, in 1943, his long didactic career at the Bucharest Faculty of Construction and then at the Hydraulics Department of the Polytechnic Institute of Bucharest began and lasted until 1974. His concern for equipping the department's laboratories with the didactic and experimental materials required for the adequate training of future engineers was particularly commendable. The research work he performed at the Applied Mechanics Institute of the Romanian Academy materialised into the following contributions: *Studiul privind aplicarea metodelor numerice în domeniul hidraulic* (*Study on the Application of Numerical Methods in Hydraulics*); *Studiul metodei reţelelor aplicate în hidraulică* (*Study of the Method of Applied Networks in Hydraulics*).

Research on scale models conducted in the Academy's laboratories led to the optimisation of the hydrotechnical plants of Bicaz, Sadu, Moroieni, Porțile de Fier. He authored a manual for hydrotechnical engineers (*Manualul inginerului hidrotehnician*) (Dumitrescu and Pop 1969), which is a particularly important instrument for engineers working in the field of hydrotechnical constructions.

One flagship work for the theoretical development of fluid mechanics is *Introducere matematică in mecanica fluidelor* (*Mathematical Introduction into Fluid Mechanics*), written by Romanian Academy Member **Caius Iacob,** published in 1952 by the Publishing House of the Romanian Academy (Iacob 1952) and subsequently translated by the Editions Gauthier-Villars publishing house in 1959. He pursued his higher-education studies at the Bucharest Faculty of Mathematics (1928–1931), obtaining his bachelor's degree at the age of 19. He continued his doctoral studies at the Faculty of Sciences of the University of Paris, where, on 24 June 1935, he defended his thesis titles *Sur la détermination des fonctions harmoniques conjuguées par certaines conditions aux limites. Applications à l'hydrodynamique*, under the supervision of Professor Henri Villat. Once back in Romania, he dedicated his life to higher education and scientific research, climbing the academic ladder from the initial position of assistant professor (from 1935 at the Polytechnic School of Timișoara) all the way to that of professor at the Faculty of Mathematics of the University of Bucharest (where he reached retirement in 1982). Meanwhile, in 1938 and then between 1942 and 1950, he was active at the University of Cluj as well, first as an assistant professor, then a lecturer of general mathematics, only to be appointed professor of mechanics at the age of 31. He moved to Bucharest, but returned to Cluj in 1967–1969 as associate professor at the new Department of Fluid Mechanics created at the Faculty of Mechanical Mathematics.

Another figure at the University of Cluj who stood out due to his remarkable results in fluid mechanics is Prof. **Petre Brădeanu**, whose works focused on the border bed theory, convective heat transfer, the mechanics of a point of variable mass, and the motion of rockets.

Interested in the geometrical aspects of fluid motion, **Gheorghe Gheorghiev**, professor at the University of Iași, studied and described from a geometrical perspective surfaces containing one stream line each and another of vortex lines in the permanent motion of a barotropic liquid, thus determining the conditions for these surfaces to withstand an infinity of such motions. He elaborated studies on the permanent motion of certain ideal fluids and studied the helical motion of fluids (1955–1956), then he established a series of relations between the algebraic invariants of the deformation tensor and those of the fluid's motion (papers of 1962). He studied the motion for which the deformation tensor is null and the deformation tensor of the velocity field.

Fluid mechanics developed as a subject in Romanian universities thanks to pursuits supported by highly trained scientists in the field of mathematics. Holder of a Ph.D. in physics-mathematics, **Elie Carafoli** attended fluid mechanics and aeronautics courses at the Sorbonne, then worked at the Aerotechnical Laboratory of Saint-Cyr, where he constructed an aerodynamic tunnel intended for visualising the motion of fluids. Carafoli tackled the issue of general motion around an outline. He conducted research on monoplane wings and conical motions in a supersonic regime, thus initiating the first course in aeronautics.

The turbulent motion regime is an especially complex phenomenon within fluid dynamics, one which has been studied by many scholars and researchers, physicists, or engineers for over a century. In Romania, **Elie Carafoli** and **V. N. Constantinescu** pursued such research, obtaining remarkable results in the fundamental study of turbulence. Professor V. N. Constantinescu, one of the greatest specialists in the field of fluid lubrication, is the author of the volume *Teoria lubrificației turbulente* (*Theory of Turbulent Lubrication*) (Constantinescu 1965), which was translated into English by the Atomic Energy Commission. Issued by the Publishing House of the Romanian Academy, the volumes titled *Dinamica fluidelor incompresibile* (*Dynamics of Incompressible Fluids*) (1981) (Carafoli and Constantinescu 1981), *Dinamica fluidelor compresibile* (*Dynamics of Compressible Fluids*) (1984) (Carafoli and Constantinescu 1984), written by E. Carafoli and V. N. Constantinescu, are works of reference in the field. *Dinamica fluidelor vâscoase în regim laminar* (*Dynamics of Viscous Fluids in a Laminar Regime*) (1987) (Constantinescu 1987) and *Dinamica fluidelor vâscoase. Stabilitatea mișcărilor laminare* (*Dynamics of Viscous Fluids. Stability of Laminar Motions*) (1993) (Constantinescu 1993) by Romanian Academy Member V. N. Constantinescu continue the presentation of the issues specific to fluid motion. In the volume *Dinamica fluidelor în regim turbulent* (*Dynamics of Fluids in a Turbulent Regime*), published in 2008 (Constantinescu et al. 2008), the topic of turbulent lubrication is extensively discussed by V. N. Constantinescu, S. Dănăilă, and S. Găletușe, with concrete examples as to the calculation and design of various types of sealing.

The development of Romanian higher education often goes hand in hand with the matching development of technology. An example in that sense is that of engineer **Teodor Oroveanu**, who became Doctor of Engineering in 1967 and then Docent Doctor in 1970. He worked as an engineer at the Central Workshops of the former Steaua Română Company in Câmpina, then at the Processing-Metallurgy Industrial Plant (1945–1949). From 1949 to 1968, he worked consistently at the Institute of Fluid Mechanics, while being a lecturer (from 1951) and professor (from 1968) at the Petroleum and Gas Institute of Bucharest. In 1969, as the institute moved, he was transferred to Ploiești and was appointed head of the Hydraulics Department (1971–1984); in 1990, he became consulting professor at the Petroleum-Gas University of Ploiești. He held courses in Baku, Freiburg, Moscow, Paris, Rennes, Toulouse. He conducted an intense scientific activity, mainly oriented towards fluid mechanics, particularly in the fields of the flow of fluids through porous media, convective diffusion in fluids, the motion of viscous fluids, with a special focus on the extraction and transport of petroleum and gas. He followed the manner in which the results of his research were used in technology, as many of them directly served to elaborate calculation and design methods, especially in the oil industry. He conducted studies on the exploitation of oil deposits found in fractured rocks and on the hydraulic fracturing of deposits with reduced permeability. He introduced modern calculation methods for pipes for petroleum, petroleum products, and gas, including optimisation procedures for the latter, using computers for the first time in Romania. The results of his research materialised into numerous written works, the most outstanding of which are *Mecanica fluidelor* (*Fluid Mechanics*), 2 vol., (Carafoli and Oroveanu 1955); *Mecanica fluidelor vâscoase* (*Mechanics of Viscous Fluids*), (Oroveanu 1967), the monographs *Scurgerea fluidelor prin medii poroase neomogene* (*The Flow of Fluids through Non-homogeneous Porous Media*) (Oroveanu 1963); *Scurgerea fluidelor multifazice prin medii poroase* (*The Flow of Multiphase Fluids through Porous Media*) (Oroveanu 1966), *etc.*

The phenomenon of cavitation is present in almost all the fields of modern technology and industry where there are liquids in motion. Cavitation is mainly identified through its effects characterised by the destruction of solid walls, strong oscillations and vibrations, and a decrease in efficiency when present in hydraulic machines. The first book of this type in Romania which distinguishes itself from other similar works due to its unitary character is *Cavitația* (*Cavitation*) (two volumes) by Romanian Academy Member **Ioan Anton**, published in 1984 (Anton 1984). It is based on a vast set of materials from both international technical and scientific literature and the wealth of experience of the school of hydraulic machines of the Polytechnic school of Timișoara.

The unprecedented development of computing technology led to a new approach to the study of issues related to fluid dynamics. Thus, the first pursuits related to numerical fluid mechanics appeared at the Faculty of Aircraft of the University Politehnica of Bucharest. One work in this field, written by professors Sterian Dănăilă and Corneliu Berbente, is the monograph *Metode numerice în mecanica fluidelor (Numerical Methods in Fluid Mechanics*) (Dănăilă and Berbente 2003). Basically, all the important chapters are covered as to obtaining, via numerical calculation methods, the solutions for differential equations with partial derivatives describing fluid flows in various regimes: incompressible, compressible, stationary and non-stationary, non-viscous and viscous, laminar and turbulent.

In 1990, the National Centre for Complex Fluid Systems Engineering (CNISFC, Centrul Național pentru Ingineria Sistemelor cu Fluide Complexe) was created at the Politehnica University of Timișoara, possessing a parallel computing research laboratory equipped with a network of computers and work stations for students. One remarkable monograph which uses the Fluent software is *Mecanica fluidelor cu Fluent* (*Fluid Mechanics with Fluent*), elaborated by a group formed by Diana Broboană, Tiberiu Muntean, and Corneliu Bălan of the University Politehnica of Bucharest (Broboana et al. 2005).

Fluid power drives and hydraulic automations are another chapter which registered spectacular development in the new context determined by new technics, high-performance technologies, and expected quality requirements. A group of teachers and researchers at the Technical University of Cluj-Napoca, coordinated by Professor Liviu Deacu, elaborated an excellent synthesis of the studies and research in the field of adjustable pumps and motors in the work *Tehnica hidraulicii proporționale* (*Technology of Proportional Hydraulics*) *(1989)* (Deacu et al. 1989). It presents, in a coherent manner, both experimental studies and numerical analyses for a wide range of adjustment types, in accordance with the accomplishments of a team of researchers at the Institute for Fluid Power Drives and Control in Aachen, Germany.

Significant theoretical and experimental developments in the systematics of pneumatic and fluid power drives are owed to researchers at the University Politehnica of Bucharest led by Professor Nicolae Vasiliu, who supervised the drafting of the work titled *Transmisii hidraulice și electrohidraulice* (*Hydraulic and Electrohydraulic Transmissions*) (Vasiliu and Vasiliu 2005*)*.

Created in 2005–2007 in order to bring together the research efforts regarding the hydrodynamics of vortexes and applications, the ACCORD-FluiD academic consortium enjoyed the contribution of specialists from the following Romanian higher-education institutions: the Politehnica University of Timișoara, the Romanian Academy—the Timișoara branch, the University Politehnica of Bucharest, the Technical University of Civil Engineering of Bucharest, the Dunărea de Jos University of Galați, the Technical University of Cluj-Napoca, the Eftimie Murgu University of Reșița, the 'Gheorghe Asachi' Technical University of Iași. The research thus performed was summarised in the monograph *Vortex Dominated Flows* (Susan-Resiga et al. 2007).

5.2 Hydraulic Machines and Equipment

The theoretical foundations of fluid mechanics have exerted a strong influence upon industrial development worldwide, along two lanes:

(a) *The appearance and development of hydraulic machines.* These are prime movers inside which a transformation of hydraulic energy into mechanical energy, or vice versa, occurs. Depending on the direction of the transformation, they are called either hydraulic engines (turbines) or hydraulic generators (pumps). Romanian Academy Member Anton (2011) Visuri. Împliniri. Amintiri de la Politehnică (1943–2011) (Dreams. Accomplishments. Memories from the Polytechnic (1943-2011)). Politehnica Publishing House, Timișoara), defines hydraulic turbines or 'hydraulic engines' as those machines which transform hydraulic energy into mechanical energy, and hydraulic pumps or 'generators' as those machines which transform mechanical energy into hydraulic energy. The transformation of hydraulic energy into mechanical energy takes place inside a rotating part equipped with blades or buckets called a rotor. This transformation is carried out with high efficiency and at relatively high rotative speed;

(b) *The appearance and development of hydraulic control and adjustment elements and systems.* Fluid power drive systems are physical drive systems made up of a generator (pump), an engine and adjoining installations. The role of the generator (i.e. hydraulic pump) is to produce hydraulic energy. The engine receives that energy in the form of a mass of liquid set into motion by the generator and transforms it into mechanical energy. The adjoining installations are secondary elements which aid the main process of transformation of hydraulic energy into mechanical energy. Such installations can be: test gauges, connecting pieces, rigid and flexible pipes, faucets, filters, radiators, pressurised tanks, lubrication and outlet orifices, connection valves. The resulting mechanical energy is intended to set an end device into motion.

Hydraulic Machines

Sebastian MUNTEAN

Ladislau Vekas

Towards the end of the 19th century, hydraulic turbines were increasingly used in Europe. This was the result of two main factors, namely: manufacturers specialising in turbines and generators, thus offering adequate equipment proven to be safe to operate and economically efficient; the growing demand for electrical energy due to the ever more powerful development of the industry. These elements, very suggestively summarised by the saying '*technology push and market pull*', were, naturally, noticed by entrepreneurs and local administrations in Romania. The existence of a long-standing tradition of the use of hydraulic energy by means of a great variety of wheels made it impossible to ignore the new technological progress even in its early stages. Hydroelectric plants were built at: the Peleș Castle, with two 60 HP Pelton turbines—1884; Grozăvești, Bucharest, with two 135 kW Girard turbines—1889; Băile Herculane, with two 130 kW Francis turbines—1892; the Topleț Works, Caraș-Severin, with one 110 kW Girard turbine—1893, followed by three 120 kW Francis turbines; Sadu I, Sibiu, with two 270 HP Girard turbines—1897; Sinaia, with four 360 HP Francis turbines—1899; Bocșa, Caraș-Severin, with one 100 kW Francis turbine—1900.

By the year 1900, 19 hydroelectric plants with circa 4,115 kW in installed capacity were built in Romania. Between 1901 and 1918, 35 hydroelectric plants with circa 19,740 kW in installed capacity were completed and 26 with an installed capacity of 35,240 kW (including the expansion and re-equipping of certain extant plants) between 1919 and 1945. The hydroelectric plant with the highest installed capacity was the Dobrești one, from 1930, equipped with four horizontal Pelton turbines made by Voith, of 5,650 HP each. The hydroelectric plants built in Romania before the Second World War added up to an installed capacity of little over 59,000 kW (see Chapter 16 The History of Energy). The equipment used in these plants was imported, primarily from Germany. It is noteworthy that there was intense focus on building hydroelectric plants in Romania during the interwar period. The most representative work in this field belongs to Professor Dorin Pavel from Bucharest, who, in the volume *Plan général d'aménagement des forces hydrauliques en Roumanie* (Pavel 1933), inventoried and established the general plan of 567 hydroelectric plants on the territory of the Greater Romania, comprising a plain view and a longitudinal profile, including the plants' lakes, galleries, canals, and buildings. Before this work, in 1929, the paper *Les forces hydrauliques en Roumanie* (Pavel 1929) was published.

The manufacturing of hydraulic turbines in Romania was a later initiative, which occurred around the time of the Second World War. Although, even before the war, *Fabrica Frații Schiel* (the Schiel Brothers' Factory) of Brașov produced *Francis-system water turbines with a vertical and horizontal shaft, for all water falls* as well (Wollmann 2010), this activity most likely ceased due to the nationalisation.

The data found so far indicate that the first factory to produce hydraulic turbines in Romania was that of the Schiel brothers in Brașov: *Brüder Schiel Maschienen-fabrik AG* (for more details, see Chap. 7 The Machine Building Industry). Thus, as shown in (Wollmann 2010), the factory drew up the documentation and delivered the equipment for the hydrotechnical milling system of Valea Seacă (Sânzeni commune, Covasna County), in 1922 (Fig. 1).

The point of departure for the extended manufacturing based on one's own design, was the Polytechnic school of Timișoara, where the training of future engineers developed simultaneously with the research in the field of hydraulic machines. Thus, in 1928–1929, Professor Pompiliu Nicolau created the first laboratory of hydraulics and hydraulic machines with a test bench for open-circuit hydraulic turbines (Fig. 2).

From 1931 onwards, the subject of hydraulic machines was taken over by young lecturer Aurel Bărglăzan. The name of this eminent professor and engineer is associated with the founding of the Romanian school of hydraulic machines in Timișoara. The remarkable achievements of the members of the Hydraulic Machines Laboratory (Fig. 3) of the Timișoara Polytechnic Institute were acknowledged through the granting of the State Award in 1953: Prof. A. Bărglăzan, Prof. V. Gheorghiu, Eng. I. Anton, Eng. I. Preda, Eng. V. Anton, mechanic I. Drăgălina.

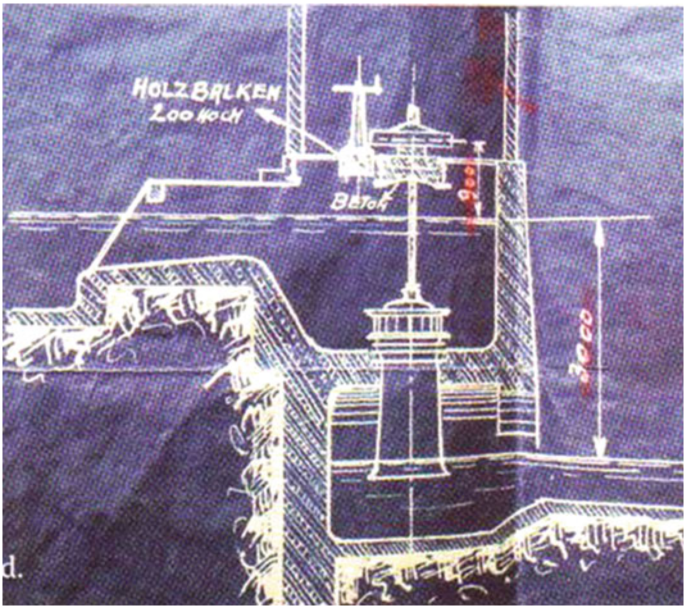

Fig. 1 Detail from the original plan of 1922 as to the manner of positioning the Francis turbine (Wollmann 2010)

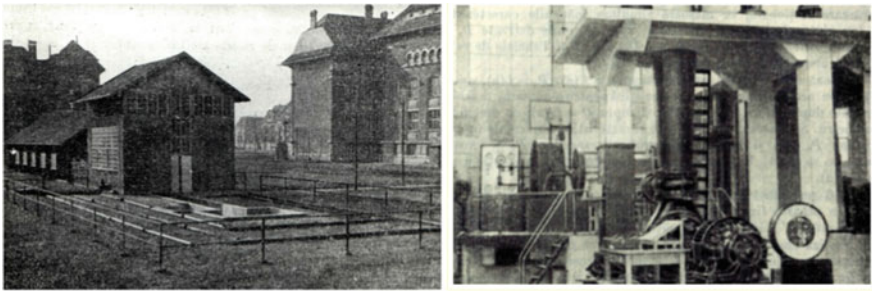

Fig. 2 The Hydraulic Machines Laboratory of Timișoara, 1928

Fig. 3 The Hydraulic Machines Laboratory of Timișoara, 1953

The Timișoara school of hydraulic machines created by Prof. Aurel Bărglăzan, corresponding member of the Romanian Academy, included the members of the Hydraulic Machines Laboratory of the Timișoara Polytechnic Institute and those of the Cavitation Department of the Technical Research Centre (CCT, Centrul de Cercetări Tehnice) of the Timișoara Scientific Research Base of the Academy of the Romanian People's Republic.

The Technical Research Centre of the Academy's Department of Technical Sciences was founded in 1956 through the decision of the Academy Presidium and included four departments: the Welding Department (Romanian Academy Member Cornel Miklosi); the Fatigue and Fragile Fracture in Metals Department (Prof. Ștefan Nădășan, corresponding member of the Academy of the Romanian People's Republic), the Cavitation Department (Prof. Aurel Bărglăzan, corresponding member of the Academy of the Romanian People's Republic) and the Building Materials Department. The leadership of the establishment consisted of Romanian Academy Member Mikloşi (1956–1963), Romanian Academy Member

Ștefan Nădășan (1963—1967), and Prof. Ioan Anton, corresponding member of the Academy of the Romanian People's Republic, as director (1967–1970).

Professor Aurel Bărglăzan's collaboration with the Reșița works materialised in 1939 into a pump for supplying the furnace cooling system. The Bărglăzan pump, as it was called, made to be used by its producer, was subsequently built and delivered in response to orders. After that, a Francis-type hydraulic turbine was produced in Reșița based on documentation drawn up by a team led by Eng. Andrei Berzănescu, to be installed in Moldova Nouă (Caraș-Severin) after the war, in 1946. A 6 HP Pelton group was also made at the mechanical workshops in Anina, which were installed on Mărghitaș lake by Eng. Zeno Jumanca. Furthermore, Prof. Cornel Miklosi, most likely aided by his colleague, Prof. Bărglăzan, built a Pelton-turbine group for the cabin on (Mount) Muntele Mic.

In 1948–1960, even though there were already engineers specialised in hydraulic machines in Reșița and a strong research team was found in Timișoara, there was a lack of trust in the Romanian industry's capacity to produce hydro-equipment. Thus, a series of plants were equipped with imported products. Such was the case of the plants of Moroieni (Ialomița County)—15 MW, Sadu V (Sibiu County)—22.5 MW, Stejaru (Bistrița-Năsăud County)—210 MW, Roznov I—14 MW, and Vidraru (Argeș County)—220 MW. It is important to mention that the technical design for the Argeș plant was done at Reșița, yet the equipment was acquired from abroad.

There were two exceptions during this time. The first was the building at Reșița, in collaboration with Timișoara, of the equipment for the Crăinicel plant, which belonged to the works; it consisted of two aggregates with 1,100 kW Francis turbines and two with 2,900 kW Pelton turbines. The Pelton turbines had two different rotors on the same axle (Fig. 4). The concept of the Crăinicel facility (Fig. 5) and the task of supervising its execution belonged to Prof. Dorin Pavel. The second set to be built was the one for the Târgu Mureș plant, consisting of three 550 kW axial flow turbines, two helical ones, and a Kaplan one. The trials for these models were conducted at the laboratory of the Polytechnic school of Timișoara, while the projects were carried out by the mixed team created and led by Prof. A. Bărglăzan and A. Berzănescu, chief builder of the Reșița facility. It is important to mention that this gave rise to a professional group capable of initiating the future projects in this field.

In 1960, the devising of hydraulic turbines was initiated at Reșița, led by Eng. Flore Coste, who started the designing of the hydraulic turbines (and then generators with related installations as well) ordered by the Ministry of Electrical Energy for the Bistrița-Aval plant: 10 turbines with a power of 8–10 MW for a 20 m water fall and a rotative speed of 250 rpm—Roznov II, Zănești, Costișa, and Bacău II; 8 turbines with a power of 11.5–12.5 MW for a 15 m water fall and a rotative speed of 136.4 rpm—Pângărați, Racova, Gârleni, and Bacău I; 4 turbines of 5.5–6 MW for 15 m water falls and 214.4 rpm—Piatra Neamț and Buhuși; 2 turbines of 23.4 MW for a 26.2 m water fall and 166.7 rpm—Vaduri.

It is necessary to note that Reșița did not possess any test bench at the time, so the testing was carried out in Timișoara, at Prof. Bărglăzan's laboratory, until 1960 (the professor passed away in September), then under the leadership of Lecturer Ioan Anton. The laboratory was expanded to include a cavitation bench with a rotor

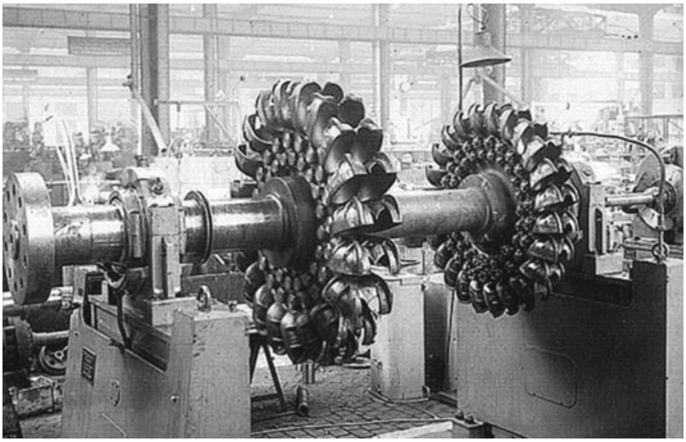

Fig. 4 The Pelton turbines at the Crăinicel plant

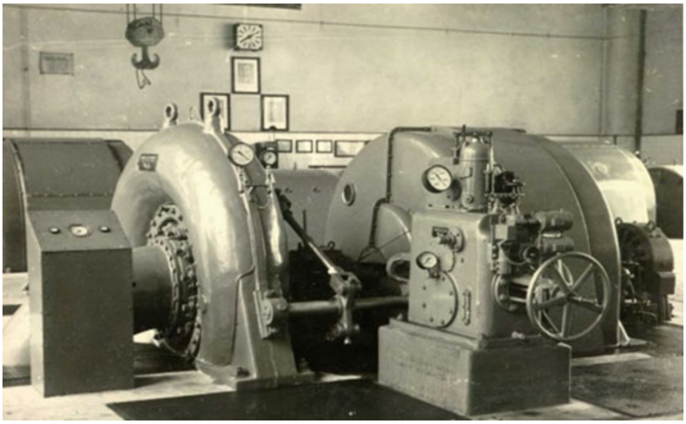

Fig. 5 One of the Francis-turbine groups at Crăinicel

diameter of 200 mm, then 400 mm, which made it possible to conduct tests at IEC international norms (Fig. 6). The energetic and cavitational characteristics of the studied Kaplan rotors with a 400 mm diameter were established in order to mitigate the energy-related and cavitational scale effects for the turbines of the Porțile de Fier I (Fig. 7).

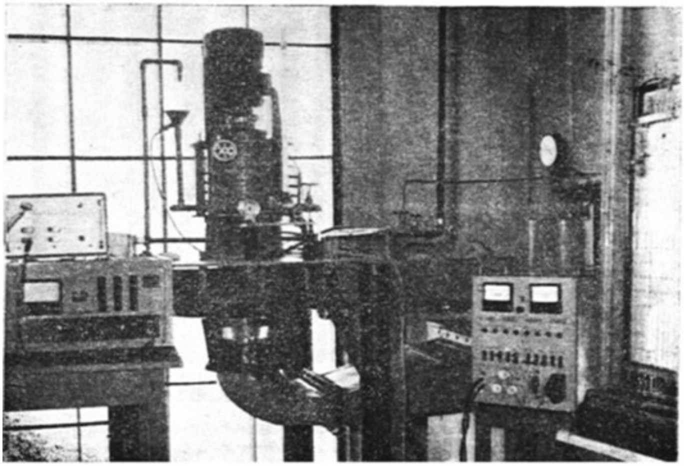

Fig. 6 The cavitation bench for rotors with a 200 mm diameter in Timișoara

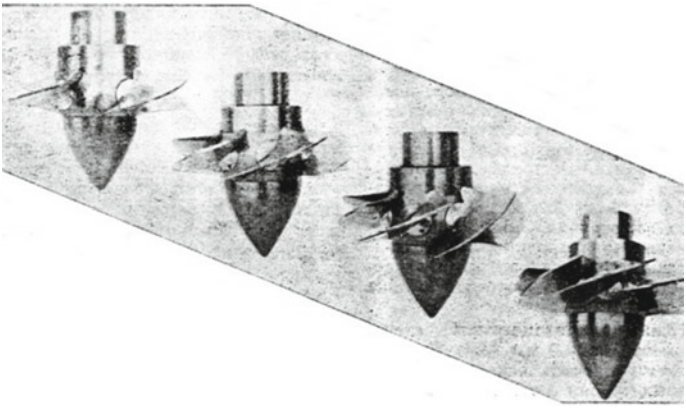

Fig. 7 Models of Kaplan rotors with a 400 mm diameter for the Porțile de Fier I turbines

The activity of the Timișoara school of hydraulic machines focused on basic research, obtaining world-level result in the following fields: turbo-machine hydrodynamics, the hydrodynamics of profile networks, cavitation in hydraulic machines and equipment, and scale effects. Prof. I. Anton, in collaboration with heads of works I. Preda, Viorica Anton, Fr. Gyulai, and Dr. Eng. E. Sisak, conducted in situ measurements regarding cavitation in hydraulic turbines, identifying it at the entry of the aspirating tube due to noises and vibrations far above the ones stipulated by IEC norms. Dr. Eng. V. Câmpian performed the theoretical and experimental studies on bulb and reversible bulb turbines (pump-turbines) by designing and testing reversible rotors. The designing of such rotors was carried out using Prof. O. Popa's method for sizing profile networks based on compliant representation. The results of the research conducted over five decades by the hydraulic machines team of Timișoara in the field of hydraulic turbines were published in the volumes *Turbine hidraulice* (*Hydraulic Turbines*) (1979) (Anton 1979) by I. Anton, *Hidrodinamica turbinelor bulb și a turbinelor-pompe bulb* (*Hydrodynamics of Bulb Turbines and Bulb Turbine-Pumps*) (1988) (Anton et al. 1988) by I. Anton, V. Câmpian, and I. Carte, while those in the field cavitation in hydraulic machines and systems were published in *Cavitația* (Cavitation) vol. II (1985) (Anton 1984) by I. Anton, and those regarding the energy-related and cavitational scale effects in hydraulic turbines applied to the Kaplan turbines of Porțile de Fier I in the volume *Energetic and Cavitational Scale Up Effects in Hydraulic Turbines* (2002) (Anton 2002).

The Timișoara school of hydraulic machines led by Romanian Academy Member Ioan Anton included the members of the Hydraulic Machines Department of the Faculty of Mechanics of the Traian Vuia Polytechnic Institute of Timișoara and those of the Cavitation Department of the Technical Research Centre (CCT) of the Timișoara Scientific Research Base of the Academy of the Romanian People's Republic, which was dissolved in 1970 (Anton and Silaş 1999). The team of the Cavitation Department formed the core of the Centre for Hydrodynamics, Cavitation, and Magnetic Liquids (CCHCLM, Centrul de Hidrodinamică, Cavitație și Lichide Magnetice) founded in 1971 at the Politehnica University of Timișoara. Thanks to the efforts of Romanian Academy Member Ioan Anton, in 1996, the Timișoara branch of the Centre for Basic and Advanced Technical Research (CCTFA, Centrul de Cercetări Tehnice Fundamentale și Avansate) of the Romanian Academy was founded by government decision, thus ensuring the continuity over time of the CCT. The CCTFA comprises three departments coordinated by a full or corresponding member of the Romanian Academy: the Hydrodynamics, Cavitation, and Magnetic Liquids Department (Romanian Academy Member Ioan Anton and currently Dr. Ladislau Vékás), the Metal Construction and Welding Department (Romanian Academy Member Dan Mateescu and currently Romanian Academy Member Dan Dubină), the Electromechanics, Vibration, and Vibro-Percussion Department (Romanian Academy Member Toma Dordea and currently Romanian Academy Member Ion Boldea). The CCTFA was led by Romanian Academy Member Ioan Anton (1996–2008) as its honorary director and subsequently by Dr. Ladislau Vékás, corresponding member of the Romanian Academy and the centre's director (2008).

It constituted the de facto certification of the technological capabilities to build hydroaggregates in Romania, at Reșița. The successful activation of the aggregates of Bistrița-Aval, followed by Argeș-Aval, coincided with the beginning of the preparations for the construction of the Porțile de Fier I facilities. In order to support design in that field, the 1 Ianuarie 1966 Institute for the Design of Energy Equipment of Reșița (for hydroelectricity and thermal energy) was created, only to be turned the following year into the *Reșița Institute for Research and Hydroenergy Equipment Design* with a branch in Timișoara; the part of the institute in charge of thermal equipment was separated and moved to Bucharest once the manufacturing of thermal turbines began. The position of director of the institute was entrusted

Table 1 The turbines built by UCM Reșița up to the year 2000

No.	Turbine type	Amount	Power (MW)
1	Kaplan	209	2,580
2	Pelton	6	374
3	Francis	86	2,762
4	Bulb	13	298
5	Reversible bulb	21	292
Total		335	6,641

to Eng. A. Bitang[1], who used to be the plant's director of technology. The institute continued to support the entire design of hydroelectric equipment. Offices were created in Reșița and Timișoara, and, in 1973, the guarantee bench in Reșița became operational, its equipment being at the level of international technology in the field. This made it possible to conduct intense research, while collaboration with the Polytechnic school of Timișoara reached a high scientific level. An entire string of high-performance achievements followed, including the first exported products, which were two hydroaggregates with 18.2 MW Francis turbines for a 36 m water fall, with a rotative speed of 166.7 rpm and a rotor diameter of 2.8 m, cast in one piece. Up until 1999, Reșița designed and delivered over 330 aggregates, amounting to a total power of over 6,600 MW. Furthermore, a standardised range of turbines was designed, many of which were exported. According to a prospectus of UCM Reșița, the turbines built until 2000 are the ones in Table 1 (Voia 2011).

It is necessary to add two special observations regarding the turbines of Lotru and those of Porțile de Fier. For Porțile de Fier I, UCM Reșița produced 6 Kaplan turbines of 178 MW with a rotor diameter of 9.5 m and a rotative speed of 71.5 rpm; by rotor diameter, they were the largest in the world at the time. Three groups were to be built entirely in Romania. To that purpose, even from the technical project planning stage, the engineers of the Reșița Institute and the plant's technology specialists participated in the making of the design plans at the LMZ plant in Leningrad. It was a particularly useful experience, in terms of both design and technology. The same work method, used for the bulb turbines of Porțile de Fier II, made it possible to build at Reșița 6 of the 8 bulb turbines of 28 MW, 7.5 m in diameter and 62.5 rpm, plus two groups for the Gogoșu plant and two for the plant in Serbia. As there were no prospects of building any similar ones in the future, for the Pelton turbines of Lotru, of 175 MW and 375 rpm, produced in collaboration with the Neyrpic company (France), the builders limited themselves to adapting the design to plant technology.

[1] Eng. Alexandru Bitang held the position of director general of UCMR in 1974-1983 and, in 1983-1986, he was the technical director of the Reșița-Renk Romanian-German reducer factory.

Hydraulic Control and Adjustment Elements and Systems

Liviu VAIDA

In the first stage of the manufacturing of control and fluid power drive elements (the period after the Second World War), production in Romania was channeled towards satisfying the need for such equipment, as it was required in order to produce agricultural machines, equipment for the railway, naval, and oil industry, and military equipment.

Table 2 presents the main enterprises producing hydraulic equipment on Romanian territory and their historical evolution. The first column contains the current name (or last name for those enterprises which have been dissolved).

In 1950-1965, there emerged several research and design units of national interest called ‘institutes’ in Romania within which departments for fluid power drives called ‘design workshops’ were created. At present, the development of hydraulic control and adjustment elements and systems is supported by several production and research units in Bucharest, Iași, Râmnicu Vâlcea, Sibiu, as well as by the research teams of the ‘Gh. Asachi’ Technical University of Iași (D. Călărașu), the Technical University of Cluj-Napoca (L. Deacu), the University Politehnica of Bucharest (N. Vasiliu,), the Politehnica University of Timișoara (V. Bălășoiu). These institutions founded the FLUIDAS National Professional Association of Hydraulics and Pneumatics with the aim of stimulating and creating a favourable environment for research, development, and innovation activities, as well as for production, distribution, and use activities. Under the aegis of this professional association, the HIDRAULICA magazine has been published at national level since 1998.

Table 2 The main producers of hydraulic equipment

Factory	Year of founding, evolution	Main products
AVERSA Bucharest	1882 the foundry and mechanical workshop are founded 1941–1945 occupied by the army 1948 nationalised under the name of the Pump Factory 1965 its name is changed into the Bucharest Pump Plant 1990 privatised 2006 named AVERSA again; becomes insolvent 2012 goes bankrupt 2013 acquired by the Benevo group 2016 ceases its activity	Various small parts Pumps for extinguishing fires Pumps for the industrial, agricultural, and energy sectors From 1985 onwards, it produces hydraulic pumps and installations for the Cernavodă nuclear plant

(continued)

Table 2 (continued)

Factory	Year of founding, evolution	Main products
HESPER Bucharest	1877 Mechanical workshop in Ghencea, Bucharest 1887 the Wolff factory near Carol Park is founded 1948 nationalised and named Steaua Roșie (Red Star) Bucharest 1974 the production of hydraulic equipment and installations begins 1991 turned into a joint-stock company called HESPER	Installations for steam locomotives Central-heating installations for industrial and civil buildings Vacuum pumps and equipment for nuclear plants, and starting from 1991, hydraulic pumps and engines with gears, hydraulic engines and power-assisted steering, simple and complex hydraulic installations upon assignment
ISEH Focșani	1970 tool factory 1973 new department for hydraulic equipment 1980 development, modernisation 1991 closed down following a fire	Tools Distributors A family of throttles and one of check valves Monoblock and proportional batteries (projects of the Hydraulics and Pneumatics Research Institute, IHP) A family of general-use benches (IHP projects) of medium and high complexity
HIDROSIB Sibiu	1975 founded (broke away from BALANTA Sibiu) 2004 incorporated into ADVANCED HANDLING 2006 integrated into METALRAX GROUP PLC 2009 perfecting its activity	Hydraulic equipment and pneumatic pumps Hydraulic and manipulation equipment A modernisation programme followed Unique hydraulic components, solutions in the field of fluid power drives Design and production of hydraulic systems and circuits
HERVIL Râmnicu Vâlcea	1981 created as a hydraulic equipment manufacturer 1987 attains envisaged parameters 2001–2002 modernisation 2013 the WIPRO group takes over HERVIL and turns it into SC WIPRO INFRASTRUCTURE ENGINEERING SA 2013 part of it breaks away and becomes SC HERVIL ASSETS Management SRL	Hydraulic equipment, hydraulic cylinders for agriculture and the metallurgical industry, servo valves, various pumps 80% for export Hydraulic cylinders for excavators

(continued)

Table 2 (continued)

Factory	Year of founding, evolution	Main products
NAPOMAR Cluj-Napoca	1973 becomes the Grinding Machine Factory (FMR, Fabrica de Mașini de Rectificat) with a department for hydraulic equipment 1990 turns into NAPOMAR and stops making hydraulic equipment	Filters, hydraulic master-slave devices, ICENA purifying installations
BADOTHERM Vaslui	1978 the Measuring and Control Device Company is created in Vaslui 1989 restructuring 2000 integration into the BADOTHERM Dutch group	Gauges, thermometer, coupling cocks Modern measuring devices for export (75% of production)
MEFIN Sinaia	1892 metallurgical and mechanical parts factory 1948 nationalised and turned into MEFIN [Mecanică Fină (Precision Mechanics) Sinaia] 2003 incorporated into the WALBRIDGE GROUP of Detroit	Nails, nuts, screws Starting in 1953, it produces its first injection equipment In 1967, it acquires a (BOSCH) licence for injection pumps Standard (DAV) rotary pumps with a licence from LUCAS CAV England Diesel injection systems
HIDROJET Breaza	1974 a branch of MEFIN Sinaia 1990 independent company	Parts and accessories for automobiles and engines Diesel injection components
HIDRAULICA Plopeni	2003 breaks away from the Plopeni Mechanical Works	Hydraulic equipment, pumps for agricultural equipment

References

Andonie G Șt (1965, 1966, 1967) Istoria matematicii în România-Vol 1, 2, 3 (The History of mathematics in Romania-Vol 1, 2, 3). Scientific Publishing House, Bucharest

Andonie G Șt (1971) Istoria matematicilor aplicate clasice din România. Mecanică și astronomie (The History of classical applied mathematics in Romania. Mechanics and Astronomy). Publishing House of the Academy, Bucharest

Andonie G Șt (1981) Istoria științelor în România. Matematica, Mecanica, Astronomia (The History of science in Romania. Mathematics, mechanics, astronomy). Publishing House of the Academy, Bucharest

Anton I (1979) Turbine hidraulice (Hydraulic turbines). Facla Publishing House, Timişoara

Anton I (1984) Cavitația. vol l, ll (Cavitation. vol l, ll). Romanian Academy Publishing House, Bucharest

Anton I (2002) Energetic and cavitational scale up effects in hydraulic turbines. Orizonturi Publishing House, Timişoara

Anton I (2011) Visuri. Împliniri. Amintiri de la Politehnică (1943–2011) (Dreams. Accomplishments. Memories from the Polytechnic (1943–2011)). Politehnica Publishing House, Timișoara
Anton I, Silaş Gh (1999) Academia Română – Filiala Timişoara. Istoric 1951–1999 (Romanian Academy—Timişoara Branch. History 1951–1999). Orizonturi Universitare Publishing House, Timişoara
Anton I, Câmpian V, Carte I (1988) Hidrodinamica turbinelor bulb şi a turbinelor-pompe bulb (Hydrodynamics of bulb turbines and bulb turbine-pumps). Technical Publishing House, Bucharest
Agricola G (1994) De re metallica (in Romanian). Soner Publishing House, Baia Mare
Atanasiu C (2017) Academicianul Gheorghe Buzdugan și școala politehnică de rezistenţa materialelor din Bucureşti (Academician Gheorghe Buzdugan and the Polytechnic School of Materials Strength in Bucharest). AGIR Publisher House, Bucharest
Alexandru P, Dudiţă F, Jula F, Benche V (1977) Mecanismele direcţiei autovehiculelor (Vehicle steering mechanisms). Technical Publishing House, Bucharest
Atanasiu C, Mocanu DR et al (1982, 1986) Încercarea materialelor, vol 1, 2 (Testing materials. vol 1, 2). Technical Publishing House, Bucharest
Banabic D (2010) Sheet metal forming processes. Springer, Heidelberg
Banabic D (2013) Gheorghe Buzdugan—model de inginer şi dascăl (Gheorghe Buzdugan—model engineer and teacher). J Sci Policy Scientometry 1:359–362
Banabic D (2015) Sheet metal forming processes. Science Press, Beijing
Banabic D (2016) Multiscale modelling in sheet metal forming. Springer, Heidelberg
Bălan Șt, Mihăileanu Șt (1985) Istoria științei și tehnicii în România. Date cronologice (The history of science and technology in Romania. Chronological data). Academy Publishing House, Bucharest
Bălan Şt, Răutu S, Petcu V (1963) Cromoplasticitatea (chromoplasticity). Academy Publishing House, Bucharest
Banabic D, Bünge HJ, Pöhlandt K, Tekkaya AE (2000) Formability of metallic materials. Springer, Heidelberg
Bogdan RC (1968) Analiza armonică complexă şi mecano-electrică a mecanismelor plane (Complex harmonic and mechano-electrical analysis of planar mechanisms). Academy Publishing House, Bucharest
Bratu P (2002) Acustica interioră pentru construcții și mașini (Interior acoustics for buildings and machines). Impuls Publishing House, Bucharest
Broboana D, Muntean T, Balan C (2005) Mecanica fluidelor cu FLUENT, vol I (Fluid mechanics with FLUENT. vol I). Politehnica Publishing House, Bucharest
Buzdugan Gh (1956, 1957) Rezistența materialelor, vol I, II (The strength of materials, vol I, II). Technical Publishing House, Bucharest
Buzdugan Gh (1968) La mésure des vibrations mecaniques. Eyrolles, Paris
Buzdugan Gh (1980) Izolarea antivibratorie a maşinilor (Anti-vibration isolation of machines). Academiei Publishing House, Bucharest
Buzdugan Gh (2011) Probleme dinamice ale mecanicii solidelor deformabile, prezente în școala românească (Dynamic problems of solid and deformable mechanics, present in the Romanian school). In: Mihăiță M (ed) Under the dome of the Romanian Academy. AGIR Publishing House, Bucharest, Reception speeches of the engineers, pp 431–453
Buzdugan Gh, Voinea R, Sarian M, Petre A, Blumenfeld M, Pană T, Barbu E (1961) Dynamische Stabilität der Hängebrücken zur Ubenfürung von Gasrohrleigtung über Flüäse. Bulletin of the Bucharest Polytechnic Institute, XXIII:107–134
Buzdugan Gh, Fetcu L, Radeș M (1975) Vibraţiile sistemelor mecanice (Vibrations of mechanical systems). Academy Publishing House, Bucharest
Buzdugan Gh, Mihăilescu E, Radeș M (1986) Vibration measurement. Martinuss Nijhoff, Dordrecht
Burileanu Șt (1942) (1944) Curs de mecanică rațională (Rational Mechanics Course), vol 1 Kinematics, 1942, vol 2, Dynamics, 1944, Socec Publishing House, Bucharest

Cazacu O (2008) Multiscale modeling of heterogeneous materials. Wiley, New York
Cazacu O (2012) Linking scales in computation: from microscale to macroscopic properties. Elsevier, Amsterdam
Conţiu T (1957) Culegere de probleme din teoria mecanismelor şi a maşinilor (Collection of problems from the theory of mechanisms and machines). Technical Publishing House, Bucharest
Constantinescu VN (1959) On turbulent lubrication. Proc Instn Mech Engrs 173:881–900
Constantinescu VN (1963) Lubrificația cu gaze (Gas Lubrication). RPR Academy Publishing House, Bucharest
Constantinescu VN (1965) Teoria lubrificației în regim turbulent (Lubrication in Turbulent Regime). RSR Academy Publishing House, Bucharest
Constantinescu VN (1968) Lubrication in turbulent regime. US Atomic Energy Comm
Constantinescu VN (1969) Gas lubrication. American Society of Mechanical Engineers
Constantinescu G (1922) Teoria sonicității. Tratat despre transmisiunea puterei prin vibrațiuni, vol I (Theory of sonicity. Treatise on the transmission of power through vibrations, vol. I). Tipografia Cultura, Bucharest
Constantinescu VN, Al N, Pascovici MD, Ceptureanu Gh, Șt N (1980) Lagăre cu alunecare (Sliding bearings). Technical Publishing House, Bucharest
Constantinescu VN, Nica Al, Pascovici MD, Ceptureanu Gh, Nedelcu Șt (1985) Sliding bearings. Allerton, New York
Cristescu N (1955) Asupra unor probleme dinamice de teoria plasticităţii (On some dynamic problems of the theory of plasticity). PhD Thesis, University of Bucharest
Cristescu N (1958) Probleme dinamice de teoria plasticităţii (Dynamic problems of plasticity theory). Technical Publishing House, Bucharest
Cristescu N (1967) Dynamic plasticity. North Holland, Amsterdam
Cristescu N (1989) Rock rheology. Kluwer Academic, Dordrecht
Cristescu N (1990) Mecanica rocilor: modele matematice reologice (Rock mechanics: rheological mathematical models). Scientific Publishing House, Bucharest
Cristescu N, Suliciu I (1976) Vîscoplasticitate (Viscoplasticity). Technical Publishing House, Bucharest
Cristescu N, Suliciu I (1982) Viscoplasticity. Martinus Nijhoff, Leiden
Chiriacescu S (1982) Vibrații în construcția de mașini (Vibrations in machines). University of Brașov Publishing House, Brașov
Cleja-Ţigoiu S, Cristescu N (1985) Teoria plasticităţii cu aplicaţii la prelucrarea metalelor (Theory of plasticity with applications to metal processing). Bucharest University Publishing House
Carafoli E, Oroveanu T (1955) Mecanica fluidelor (Fluid mechanics). RPR Academy Publishing House, Bucharest
Carafoli E, Constantinescu VN (1981) Dinamica fluidelor incompresibile (Dynamics of incompressible fluids). Romanian Academy Publishing House, Bucharest
Carafoli E, Constantinescu VN (1984) Dinamica fluidelor compresibile (Dynamics of compressible fluids). Romanian Academy Publishing House, Bucharest
Constantinescu VN (1987) Dinamica fluidelor vâscoase în regim laminar (Dynamics of viscous fluids in the laminar regime). Publishing House of the Romanian Academy, Bucharest
Constantinescu VN (1993) Dinamica fluidelor vâscoase. Stabilitatea mișcărilor laminare (Dynamics of viscous fluids. Stability of laminar motions). Romanian Academy Publishing House, Bucharest
Constantinescu VN, Dănăilă S, Găletușe S (2008) Dinamica fluidelor în regim turbulent (Dynamics of fluids in turbulent regime). Romanian Academy Publishing House, Bucharest
Dănăilă S, Berbente C (2003) Metode numerice în dinamica fluidelor (Numerical methods in fluid dynamics). Romanian Academy Publishing House, Bucharest
Deacu L, Banabic D, Radulescu M, Rațiu C (1989) Tehnica hidraulicii proporționale (Proportional hydraulics technique). Dacia Publishing House, Cluj-Napoca
Demian T (1965) Mecanisme şi elemente constructive de mecanică fină (Mechanisms and constructive elements of fine mechanics). Didactic and Pedagogical Publishing House, Bucharest

Dimarogonas AD (1990) The origins of vibration theory. J Sound Vib 140:181–189
Dimarogonas AD, Haddard S (1992) Vibrations for engineers. Prentice Hall, Englewood Cliffs, New Jersey
Dincă F, Teodosiu C (1973) Nonlinear and random vibrations. Romanian Academy Publishing House, Bucharest, Academic Press, New York
Dowson D (1998) History of tribology. Publishing Limited, London
Dudiţă F (1966a) Transmisii cardanice (Cardan transmissions). Technical Publishing House, Bucharest
Dudiţă F (1966b) Transmissions par cardan. Editura Eyrolles, Paris
Dudiţă F (1973) Kardangelenkgetriebe und ihre Anwendungen. VDI-Verlag, Düsseldorf
Dudiţă F (1974) Cuplaje mobile homocinetice (Mobile homokinetic couplings). Technical Publishing House, Bucharest
Dudiţă F, Diaconescu D, Gogu G (1989) Mecanisme articulate. Inventica. Cinematica (Articulated mechanisms. Invent. Cinematica). Technical Publishing House, Bucharest
Dumitrescu D, Pop RA (1969, 1970) Manualului inginerului hidrotehnician, vol 1, 2 (Handbook of the hydrotechnical engineer. vol. 1, 2). Technical Publishing House, Bucharest
Filipescu Gh Em (1940) Statica construcţiilor şi Rezistența materialelor (Statics of constructions and strength of materials). Imprimeria Națională, Bucharest
Gaboș Z, Mangeron D, Stan I (1961) Fundamentele mecanicii (Fundamentals of mechanics). Romanian Academy Publishing House, Bucharest
Germani D (1942, 1945) Hidraulică teoretică şi aplicată. vol. 1, 2 (Theoretical and applied hydraulics. vol. 1, 2). Bucharest
Hangan M (1959) Une methode de calcul des structures hyperstatique dans le domaine elasto-plastique. Stud Res Appl Mech 10:795–817
Handra-Luca V (1983) Funcţiile de transmitere în studiul mecanismelor (Transmission functions in the study of mechanisms). Academy Publishing House, Bucharest
Handra-Luca V, Stoica IA (1983) Introducere în teoria mecanismelor, vol I, II (Introduction to the theory of mechanisms, vol I, II). Dacia Publishing House, Cluj-Napoca
Haret S (2010) Mécanique sociale. In: The works of Spiru Haret. Volume X. Scientific works 1878–1912. Bucharest
Harris CM, Crede ECh (1961) The shock and vibration handbook. McGraw-Hill, New York
Haton de la Goupilliere J-N (1864) Traite des Mechanismes. La theorie geometrique des organes et celle des resistances passives. Gauthier-Villars, Paris
Hertz H (1882) Über die Berührung fester elastischer Körper. J Reine Angew Math 92:156–171
Iacob C (1952) Introducere matematică in mecanica fluidelor (Mathematical introduction to fluid mechanics). Academy Publishing House, Bucharest
Iancu Șt (2009) Incursiune în istoria ingineriei de la roată la tehnologia informațională (Foray into the history of engineering from the wheel to information technology). AGIR Publishing House, Bucharest
Ionescu I (1932) Istoricul învățământului. Inginerii în România (History of education. Engineers in Romania). Cartea Românească Publishing House, Bucharest
Iosipescu N (1958, 1960) Introducere în fotoelasticitate, vol 1,2 (Introduction to photoelasticity, vol 1, 2). Academiei Publishing House, Bucharest
Ispas C et al (2007) Dinamica mașinilor și utilajelor (Dynamics of machines and equipment). AGIR Publishing House, Bucharest
Kovacs Fr K et al (1976) Metode noi în sinteza mecanismelor (New methods in the synthesis of mechanisms). Facla Publishing House, Timişoara
Lazaride G (1953) Teoria mecanismelor (The theory of mechanisms). Publishing House Polytechnic Institute of Bucharest, Bucharest
Leonăchescu N (2011) Studenţi români în Franţa (Romanian students in France). AGIR Publishing House, Bucharest
Manea Gh (1970) Organe de mașini, vol 1 (Elements of Machines, vol 1). Technical Publishing House, Bucharest

Manafu V (1959) Structura şi cinematica mecanismelor (Structure and kinematics of mechanisms). Technical Publishing House, Bucharest
Mănescu C (1893) Curs de Mecanică aplicată la Rezistența materialelor şi Stabilitatea construcţiunilor. Partea I, Fasciculul I (Mechanics course applied to the strength of materials and the stability of constructions. Part I, Fascicle I). State Printing Office, Bucharest
Mănescu C (1894) Curs de Mecanică aplicată la Rezistenţa materialelor şi Stabilitatea construcţiunilor, Partea I, Fasciculul II (Mechanics course applied to the strength of materials and the stability of constructions, Part I, Section II). Asociaţiunea Publishing House, Bucharest
Manolescu N (1955–1956) Teoria mecanismelor şi a maşinilor, vol 1–4 (Theory of mechanisms and machines, vol 1–4). CFR Institute Publishing House, Bucharest
Manolescu N, Maros D (1958) Cinetostatica şi dinamica mecanismelor (Kinetostatics and dynamics of mechanisms). Technical Publishing House, Bucharest
Maros D (1953) Note de curs de mecanisme (Mechanics course notes). Cluj Institute of Mechanics Publishing House, Cluj
Maros D (1958) Cinematica roţilor dinţate (Kinematics of gear wheels). Technical Publishing House, Bucharest
Marin A (1881) Moș Pătru sau Învățătorul de sat. Convorbiri asupra mecanicii (Moș Pătru or the village teacher. Talks on mechanics). Academy Publishing House, Bucharest
Marinca V, Herişanu N (2015) The optimal homotopy asymptotic method. In: Engineering applications. Springer, Heidelberg
Mazilu P (1982, 1983) Variationsprinzipe der Thermoplastizitaet (Band I, II). Mitteilungen aus dem Institut fuer Mechanik (Nr. 33, 37), Ruhr Universitaet Bochum
Magheți I, Savu M (2007) Teoria și practica vibrațiilor mecanice (Theory and practice of mechanical vibrations). Didactic and Pedagogical Publishing House, Bucharest
Mangeron D (1980) Teoria optimizării structurilor (Structure optimization theory). Technical Publishing House, Bucharest
Mangeron D, Irimiciuc N (1978, 1980) Mecanica rigidelor cu aplicaţii în inginerie, vol I, II (Mechanics of rigid bodies with applications in engineering, vol I, II). Technical Publishing House, Bucharest
Mangeron D, Irimiciuc N (1981) Mecanica vibrațiilor sistemelor rigide (Mechanics of vibrations of rigid systems). Technical Publishing House, Bucharest
Manolescu NI et al (1963, 1968) Probleme de teoria mecanismelor şi a maşinilor, vol 1, 2 (Problems of the theory of mechanisms and machines vol 1, 2). Didactic and Pedagogical Publishing House, Bucharest
*** (1979) Dicționar cronologic al științei și tehnicii universale (Chronological dictionary of universal science and technology). Scientific and Encyclopedic Publishing House, Bucharest
Mihăiță M, Tănăsescu F, Olteneanu M (2000) Repere ale ingineriei românești (Landmarks of Romanian engineering). AGIR Publishing House, Bucharest
Onicescu O (1956) Mecanica (Mechanics). Technical Publishing House, Bucharest
Orănescu A (1963) Teoria mecanismelor şi a maşinilor (Theory of mechanisms and machines). Didactic and Pedagogical Publishing House, Bucharest
Onicescu O (1974) Mecanica invariantivă și cosmologie (Invariant mechanics and cosmology). Academy Publishing House, Bucharest
Oroveanu T (1963) Scurgerea fluidelor prin medii poroase neomogene (Flow of fluids through inhomogeneous porous media). RPR Academy Publishing House, Bucharest
Oroveanu T (1966) Scurgerea fluidelor multifazice prin medii poroase (The flow of multiphase fluids through porous media). RSR Academy Publishing House, Bucharest
Oroveanu T (1967) Mecanica fluidelor vâscoase (Mechanics of viscous fluids). RSR Academy Publishing House, Bucharest
Pavel D (1929) Les forces hydrauliques en Roumanie. Bucharest
Pavel D (1933) Plan général d'aménagement des forces hydrauliques en Roumanie. Bucharest
Pandrea N, Stănescu ND (2015) Dynamics of the rigid solid with general constrainte by a multibody approach. Wiley, New York

Pandrea N, Popa D (2000) Mecanisme. Teorie şi aplicaţii CAD (Mechanisms. CAD theory and applications). Technical Publishing House, Bucharest
Pavelescu D (2003) The Romanian tribology evolution in the 1950–2003 Period. Analele Universității Dunărea de Jos" Galați, VIII:11–14
Popescu I (1977) Proiectarea mecanismelor plane (The design of planar mechanisms). Publishing House Scrisul Romanesc, Craiova
Popescu I (2011) Mecanisme din tehnica populară românească, în context european (Mechanisms from the Romanian folk technique, in a European context). Publisher House Sitech, Craiova
Popescu I, Dumitru N, Iordăchiţă I, Rinderu P (1977) Mecanisme biologice (Biological mechanisms). Publisher House Sitech, Craiova
Popinceanu N, Gafițanu M, Diaconescu E, Crețu S, Mocanu DR (1985) Problemele fundamentale ale contactului cu rostogolire (Fundamental problems of rolling contact). Technical Publishing House, Bucharest
Petre A (1966, 1973) Teoria aeroelasticității, vol I, Statica, vol II Fenomene dinamice periodice (Theory of aeroelasticity, vol I, Statics, vol II, Periodic dynamic phenomena). Publishing House of the Romanian Academy, Bucharest
Pelecudi C (1972) Teoria mecanismelor spaţiale (Theory of spatial mechanisms). Academy Publishing House, Bucharest
Pelecudi C (1975) Precizia mecanismelor (The precision of mechanisms). Academy Publishing House, Bucharest
Pinkus O, Sternlicht B (1961) Theory of hydrodynamic lubrication. McGraw-Hill, New York
Plăcințeanu I (1942) Mecanică rațională și analitică (Rational and analytical mechanics). Arch. D. Gheorghiu bookstore, Iași
Predeleanu M (1987) Proceedings of the international conference on computational methods for predicting material processing defects, Cachan
Radeș M (1975) Metode dinamice pentru identificarea sistemelor mecanice (Dynamic methods for the identification of mechanical systems). Publishing House of the Romanian Academy, Bucharest
Radeș M (2002) Encyclopedia of vibration. Academic Press, London
Reynolds O (1886) On the theory of lubrication and its application to Mr. Beauchamp tower's experiments, including an experimental determination of the viscosity of olive oil. Phil Trans R Soc 177:157–234
Ripianu A (1973) Mișcările vibratorii ale arborilor drepți și cotiți (The vibratory movements of straight and bent shafts). Romanian Academy Publishing House, Bucharest
Ripianu A, Crăciun I (1985) Calculul dinamic și de rezistență al arborilor drepți și cotiți (Dynamic and resistance calculation of straight and bent shafts). Dacia Publishing House, Cluj Napoca
Susan-Resiga R, Bernard S, Muntean S (2007) Vortex dominated flows. Eurostampa Publishing House, Timișoara
Silaș Gh (1968) Mecanica. Vibrații mecanice (Mechanics. mechanical vibrations). Didactic and Pedagogical Publishing House, Bucharest
Silaș Gh, Brîndeu L (1968) Sisteme vibropercutante (Vibro-impact systems). Technical Publishing House, Bucharest
Sireteanu T, Gründisch O, Părăian S (1981) Vibrațiile aleatoare ale automobilelor (The random vibrations of automobiles). Technical Publishing House, Bucharest
Schlawe H (1913) Rezistența materialelor (the strength of materials). Publishing House National School of Bridges and Roads, Bucharest
Stoenescu Al (1939) Probleme de oscilații (Oscillation problems). Polytechnic School of Bucharest, Bucharest
Teodorescu CC (1927) Essais mecaniques des materiaux faites dans le laboratoire de l'École. Bull Scient de l'École Polyt de Timişoara, 1:265
Teodorescu CC (1934) Interpretarea rezultatelor măsurătorilor la incercări de materiale (Interpretation of measurement results for material tests). Bull Scient de l'Ecole Polyt. de Timişoara 6:9

Teodorescu CC (1968) Şina continuă pe reazeme elasto-plastice (the rail continues on elasto-plastic supports). Bul St Inst Polit Cluj 11:229–239
Teodosiu C (1997) Large plastic deformation of crystalline aggregates. Springer, Berlin
Teodorescu CC (1945) Curs de Rezistența materialelor (Course on strength of materials). Romanian Railways Printing House, Bucharest
Teodorescu PP (2009a) Mechanical systems. Clasical models (vols 1, 2, 3). Springer, Dordecht
Teodorescu PP (2009b) Mechanical systems, classical models (vol 2). Springer, Heidelberg
Theocaris P, Atanasiu C, Iliescu N, Mocanu DR et al (1966, 1967) Analiza experimentală a tensiunilor, vol 1, 2 (Experimental analysis of stresses, vol 1, 2). Technical Publishing House, Bucharest
Timoshenko S (1928) Vibration problems in engineering. D Van Nostrand, New York
Tipei N (1957) Hidro-aerodinamica lubrificației (Hydro-aerodynamics of lubrication). Academy Publishing House, Bucharest
Tipei N (1962) Theory of lubrication-with application to liquid and gas-film lubrication, Stanford U.P
Tipei N, Constantinescu VN, Nica Al, Biță O (1961) Lagăre cu alunecare. Calcul, proiectare, ungere (Sliding bearings.Calculation, design, lubrication). RPR Academy Publishing House, Bucharest
Tutunaru D (1959) Mecanisme cu came (Cam mechanisms). Technical Publishing House, Bucharest
Tutunaru D (1969) Mecanisme plane rectiliniare şi inversoare (Rectilinear and reversing plane mechanisms). Technical Publishing House, Bucharest
Ursu-Fischer N (2015) Elemente de mecanică analitică (Elements of analytical mechanics). Casa Cărții de Stiință Publishing House, Cluj-Napoca
Vâlcovici V, Bălan Șt, Voinea R (1958) Mecanica teoretică (Theoretical mechanics). Technical Publishing House, Bucharest
Vasiliu N, Vasiliu D (2005) Acţionări şi comenzi hidropneumatice (Hydropneumatic actuations and controls). Technical Publishing House, Bucharest
Voia I (2011) O cometă în industria reşiţeană (A comet in the Reşiţa industry). Politehnica Publishing House, Timişoara
Voinea R, Stroe I (2000) Introducere în teoria sistemelor dinamice (Introduction to the theory of dynamical systems). Academy Publishing House, Bucharest
Voinea R, Voiculescu D (2004) Pagini din trecutul învățământului tehnic superior din România, 1818–1981 (Pages from the past of higher technical education in Romania, 1818–1981). Politehnica Publishing House, Bucharest
Voinea R, Voiculescu D, Simion P (1989) Introducere în mecanica solidului, cu aplicații în inginerie (Introduction to solid mechanics, with applications in engineering). Romanian Academy Publishing House, Bucharest
Wang QJ, Chung Y-W (eds) (2013) Encyclopedia of tribology. Springer, New York
Wolff C (1773) Compendium Elementorum matheseos universae in usum studiosae juventutis. (translated by Pataky S). Cluj
Wollmann V (2010) Patrimoniu preindustrial şi industrial în România, vol I (Pre-industrial and industrial heritage in Romania, vol I). Honterus Publishing House, Sibiu