Francesco Masi (1852–1944)

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Abstract In this paper, the figure and work of Francesco Masi is presented as an influent professor in the field of TMM in Italy. His main contribution, still of present-day significance, can be recognized in the rigorous systematization of Reuleaux's classification of mechanisms together with an analytical approach for analysis and synthesis of mechanisms. He was also a scientist and engineer in approaching design problems and teaching developments in mechanical engineering at large, and particularly in TMM, lubrication and machine drawing.

Introduction

The second half of the nineteenth century can be considered as the Golden Age for TMM (Theory of Machines and Mechanisms) since it has been developed to high levels of knowledge and practical applications. This happened mainly all around Europe during the Industrial Revolution. But in a very rich literature, some relevant works and personalities are forgotten in today's memory and consideration for the History of TMM. This is the case of most of the Italian literature on kinematics, and the Italian personalities are rediscovered only now, together with their contributions regarding TMM success, both in formation of engineers and research developments with practical applications in new machinery, as pointed out in Ceccarelli (2000).

The Italian tradition in the field of mechanics goes back to the first studies in the twelfth century and continues over the centuries with considerable contributions.

In particular, mechanics received a great boost by the work of Galileo Galilei (Galilei 1600) and Guidobaldo Del Monte (Del Monte 1577) in the sixteenth century and their influence was considerable throughout the eighteenth century too, as

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pointed out in Ceccarelli (1998, 2000). With this cultural background, new achievements were obtained in mechanics so that in the eighteenth century mechanics and mechanical engineering were addressed as separate mature disciplines apart from mathematics. Thus, specific books were written and academic courses were established in several Italian Universities.

These former developments produced a very promising environment for modern enhancements. Italian personalities are recognised and well known from the seventeenth and eighteenth centuries as, for example, Paolo Branca (Branca 1629), Evangelista Torricelli (Torricelli 1919), Guido Grandi (Grandi 1739), Paolo Frisi (Frisi 1765, 1777), Ruggero Boscovich (Boscovich 1763), only to cite some. But the cultural influence of Italian universities was reduced so that in the nineteenth century they were not considered centres of excellence as they had been in the previous century. Nevertheless, exiting activity was carried out in the field of mechanical engineering mainly with the aim of establishing a modern view of the field. Moreover, specific developments were obtained and original contributions were proposed. However, these works circulated with difficulty, even in Italy, probably since at the beginning of the century, there was a considerable number of small kingdoms and later, the main aim was the attempt to obtain a unified culture and organization when the Italian nation was achieved. Another reason for forgetting about Italian works can be the fact that the nineteenth century can be considered as a recent past in Italian culture and because of this, it is not yet considered worthy of attention. In fact, in the Italian libraries, the books of the past century are not classified in ancient funds but neither are they catalogued in modern databases. Most the time they are just stored somewhere. In addition, although memory of the personalities still exists, their works are sometimes considered as out-of-date, without taking into account that they have been useful as an important basis for modern developments.

In the second half of the nineteenth century, schools of engineering were established in most of the Italian universities, but it was only after the Decree of 3 July 1879 that the course "Kinematics Applied to Machinery" was introduced on a regular basis in the curricula of industrial engineers (Pugno 1959).

Nevertheless, only in the oldest Italian universities there was a well-established tradition and in-depth works were carried out in TMM. In fact, we have found textbooks (sometimes handwritten) for regular academic courses on TMM or kinematics given in Turin, Milan, Padua, Pisa, Bologna, Rome, and Naples.

In Turin, following the work by Lagrange and Papacino, courses on TMM were given by Carlo Ignazio Giulio (Giulio 1846), Galileo Ferraris, Domenico Tessari (Tessari 1890), Scipione Cappa (Cappa 1890). Other contributions were given by Elia Ovazza (who seems to be the first female engineer in Italy) (1890), and M. Panetti (1913).

In Milan, after Ruggero Boscovich, relevant Academic personalities can be recognised in Ernesto Cavalli (Cavalli 1882, 1889, 1908), and Gian Antonio Maggi, (Maggi 1896, 1914). Secondary works were developed by Ugo Ancona (Ancona 1896), Giusto Bellavitis (1852), and Ernesto Padova (Padova 1884).

In Bologna, after Gaetano Giorgini (1836), Domenico Chelini (Chelini 1862), and Francesco Masi (Masi 1883, 1897a) made significant contributions to TMM.

In Rome, works on TMM were written by Ugo Cerruti (Cerruti 1898) and Carlo Saviotti (Saviotti 1890). A temporally presence was Lorenzo Allievi, who published a masterpiece (Allievi 1895) on planar kinematics after giving lectures for only 1 year (Ceccarelli and Koetsier 2008). A late successor of Saviotti was Anastasio Anastasi (1908).

In Naples, an important personality on mechanics at large was Giovanni Battaglini (Battaglini 1870, 1873), and in the field of TMM Dino Padelletti (1884), had a good reputation.

In addition, professors were involved in promoting the academy and specifically TMM in more than one university. An emblematic example is Ernesto Cavalli who taught in Milan, Livorno, Pisa and Naples, as reported in his textbooks (Cavalli 1882, 1889, 1908).

The figure and work of Francesco Masi in Bologna University can be considered representative of the Italian fecundity in the field of kinematics of mechanisms, beside the relevance of his work and activity in mechanical engineering generally.

This paper is an attempt to pay due tribute to the personality of Francesco Masi (1852–1944) by surveying his teaching activities and his works that were published and circulated, unfortunately, only in the newly established Italian nation.

Biographical Notes

Francesco Masi (Fig. 1) was born on 28 February 1852 in Guastalla (Reggio Emilia). He obtained his engineer's degree in 1875 at the Royal School of Engineering in Turin. His first employment in 1875 was as professor of Physics and Mechanics at

Fig. 1 A portrait of Francesco Masi (1852–1944)

the Technical College in Cagliari. In 1877, he returned to Bologna to the Royal School of Engineering as assistant professor in the field of Mechanics of Machinery. In 1891, he was appointed full professor at Bologna University where he remained until his death on 30 November 1944 in Bologna. He married Teresa, the daughter of the famous Italian poet Giosuè Carducci, but they never had children.

Unfortunately, no detailed biographical information can be found to better characterize the wide interests that Francesco Masi had during his long life. Masi focused his attention on TMM but also on the fields of hydraulics, technical drawing, mechanics of agricultural machines by developing teaching activities in Technical Colleges and at Bologna University.

List of Main Works

The following publications can be considered as the main works os Francesco Masi. (All are written in Italian and were published in Italy only) (Masi 1927):

1. The bridge on Panaro river in Vignola, 1875.
2. The Rectory Factory for baskets in Bologna, 1880.
3. On the couplings for spherical four-bar linkages, 1880.
4. The irrigation in Modena lands, 1882.
5. Handbook for Applied Kinematics – New classification of mechanisms, 1883 (Masi 1883).
6. Determination of clear spans of bridges, 1885.
7. Methods for corrosion defense, 1885.
8. Properties of Watt curve, 1890.
9. Lectures on Hydraulics at Royal School of Engineering in Bologna, 1893.
10. Experimental methods in the teaching at Technical Professional Colleges, 1890.
11. Treatise on Civil and Industrial Constructions as co-author, published by F. Vallardi, 1890 and successive editions.
12. Drawing of mechanical parts for Technical Colleges, 1891 (Masi 1891).
13. Study of vein obtained by means of shining projections, 1895.
14. Theory of Mechanisms, 1897 (Masi 1897a).
15. New views on theoretical and experimental investigations on friction, 1897 (Masi 1897b).
16. Experiences on friction, 1897 (Masi 1897c).
17. Kinematics of mechanisms and Kinetics of machines, 1920.
18. Plough for hills, Patent, 1920.
19. Lecture Notes of Mechanics for Agriculture at the Royal Agriculture Institute in Bologna, 1926.

The variety of subjects in the above-mentioned publications shows a large variety of interests on which Francesco Masi continuously worked throughout his long academic career. In fact, he was well reputed and his memory is still persistent in the Italian Academy, not only in the field of TMM but even for his contributions in machine drawing and tribology.

Teaching Activity

Francesco Masi paid much attention to his teaching activity in the framework of both University formation of engineers and Technical Colleges for technicians. He started his career just after he obtained his engineer's degree by giving classes at a technical college in Cagliari. This experience was so fruitful for him that he continued to teach at technical colleges, even when he held the position of full professor at the University of Bologna. In particular, he devoted his efforts mainly to the subjects of technical drawing and machine design in the technical college Aldini-Valeriani in Bologna until 1906. During this period, he prepared and published the textbooks (10 and 12 on the list) (Masi 1927). In particular, the textbook on technical drawing (Masi 1891) (Fig. 2) was particularly appreciated and indeed was well used even at the level of University teaching for a long period as a significant development of the Italian tradition following the results of Quintino Sella, as pointed out in Ceccarelli and Cigola (2007).

In this textbook, Masi collected 60 drawings of the main, basic components of machines that are represented in great details for their construction, by using projections and many sections with further developments for technical views and drawing. As a conclusive example, he reported the technical drawing of a locomotive. He also included discussions and expressions both with theoretical and practical formulation for the design of mechanical parts within each drawing table. In addition, for each drawing, he explained the generalities of the technical drawing and specific particularities for the representation of details as a further development of the work by Quintino Sella, who got inspiration from Monge's Descriptive Geometry. Masi emphasized the need of writing the sizes within the figures of the drawings by quoting all the dimensions, although he recommended the use of a proper scale to indicate the real proportions. He developed technical drawing with more technical emphasis by strongly reducing the artistic features of shadows and chiaro-scuro according to Sella's approach too. Nevertheless, he recommended and used to represent through limited signs, the objects as lightened by rays at 45° from the left. He used broken-line segments as a conventional indication for different materials. Today, this textbook on Technical Drawing receives much interest from the historical viewpoint, since its completeness and clarity make it a fundamental source for understanding the historical development of technical drawing and its standardization mainly but not only in an Italian framework.

The textbook No.19 in the list (Masi 1927) on agriculture mechanics was written by Francesco Masi as a result of his teaching at the Royal Agriculture Institute in Bologna that he started in 1903.

Masi collected most of his research experiences and novel contributions in the textbooks for TMM (Masi 1883, 1897a), that are Nos. 5 and 14 in the list

Fig. 2 Cover page of the textbook on mechanical drawing by Francesco Masi, published in 1891

(Masi 1927), Fig. 3. They can be considered his main works. Both books on TMM were a great success, since they were used for a long time, even in other universities in Italy. In fact, they can still be found in the libraries of many Italian schools of engineering. Successively, he revised and completed the content for more wider TMM teaching in the textbook No.17 in (Masi 1927) that was published in 1920 but it was not successful as the other two.

Fig. 3 Cover pages of works by Francesco Masi on TMM and mechanism design: (**a**) Handbook of applied kinematics in 1883. (**b**) Theory of mechanisms in 1897

The book Masi (1897a) has a clear teaching purpose while the book Masi (1883) is much more a treatise for a new classification of mechanisms. Indeed, the book Masi (1897a) includes the content of the book Masi (1883) in a specific chapter on mechanism classification and together with Masi (1920), they complete a set that Masi prepared for the Course of Mechanics of Machinery that he taught continuously throughout his long career.

In Masi (1897a), the Theory of Mechanisms is treated both in theoretical aspects and practical applications. The first three chapters deal with the fundamentals of theoretical kinematics by explaining the kinematics of relative motion, determination of centrodes, curvature analysis of trajectory, determination of inflection circle and cycloid curves by using a graphical approach and an analytical formulation.

Chapter 4 is devoted to the study of the motion of a body on a plane by looking at the number of contact points from a kinematic viewpoint. Chapter 5 attaches the problem of instantaneous motion for the determination of the centrodes and axoides of the motion. Chapter 6 is a detailed analysis of gears with theoretical formulation and practical design rules. Chapter 7 summarizes the classification procedure that Masi elaborated in Masi (1883) as an improvement of Reuleaux's work (Reuleaux 1875).

The symbolic notation is introduced together with the notion of kinematic inversion. Successively, the general synthesis problem is discussed. A general classification of mechanisms is introduced as a function of the kinematic composition of the kinematic chain of mechanisms. This is proposed as the unifying aspect that permits us to treat all the mechanisms within a unique frame for kinematic analysis. In fact, the remaining Chapters from 8 to 15 describe all the classes of mechanisms that are included in the classification, namely linkages, gearing systems, wedges and cams, spur gears, epicyclic trains, ratchet gears, and belt transmissions.

The successful teaching approach in Masi (1897a) can be understood by looking at the clarity of the explanations that are completed by means of essential formulation and exhaustive schemes. In the discussion of each mechanism, theory is properly combined with a discussion for practical applications. In the following, examples are discussed to show Masi's approach.

In Fig. 4, kinematic schemes that are presented are useful for analyzing a Watt parallelogram. In particular, in Masi's Figure 257, a graphical procedure is outlined to draw a Watt curve of a point O of the coupler with the following procedure: by using the circles with centers A and D whose radius are AB and DC, respectively, a general point P of the curve can be determined from points M and N on the circles through the segment MP that is long like OB on the straight-line MN. N is determined by using the CB length as the radius of a circle with its center in M to intersect the circle with its center in D.

Thus, once the procedure for analysis formulation is outlined, Masi stresses the main kinematic characteristics of the Watt curve such as a sixth-order curve and the consequent order of contact of the curve with straight-line yy. A practical study of the curve is further suggested by using the variable mechanism design of Figure 258 to investigate differences in the curve as a function of the position of the tracing point O on the coupler. Results are shown in the drawn Figures from 259 to 264 that have been obtained experimentally, as reported in Fig. 5. Then, Figure 265 is proposed to outline a synthesis procedure and evaluation of the maximum deviation of the curve from the straight-line yy, through graphical determination. The sequence of the graphical construction for the synthesis is represented as a function of the data CD and angle 2α. By using angles β and λ (which are between OO_1 and yy), the maximum deviation ε can be computed as $OO_1 \sin \lambda$, whose simplification is obtained from geometric reasoning on Figure 266 to obtain $\varepsilon < AB / 2{,}592$ as a practical expression.

In Fig. 6, the study for constraining the planar motion of a body is discussed to explain the thesis that four contact points are necessary and sufficient to avoid relative translation of the body but they are only necessary to avoid relative rotation. The discussion is illustrated by looking at the intersection points of the normal lines at the contacts to determine the triangles abc and cde in Figure 55: if abc is inside cde, the relative rotation is impossible.

The extension to a general case with any number of contacts is discussed by referring No. 56 in Fig. 6 in which the basic polygon is determined by the normal lines from the contacts. Then, the conditions for possible relative rotation depend on the topology of the polygon considering the orientation of the sides: when the polygon is convex with the inside not overlapping circuits, the relative rotation is not possible.

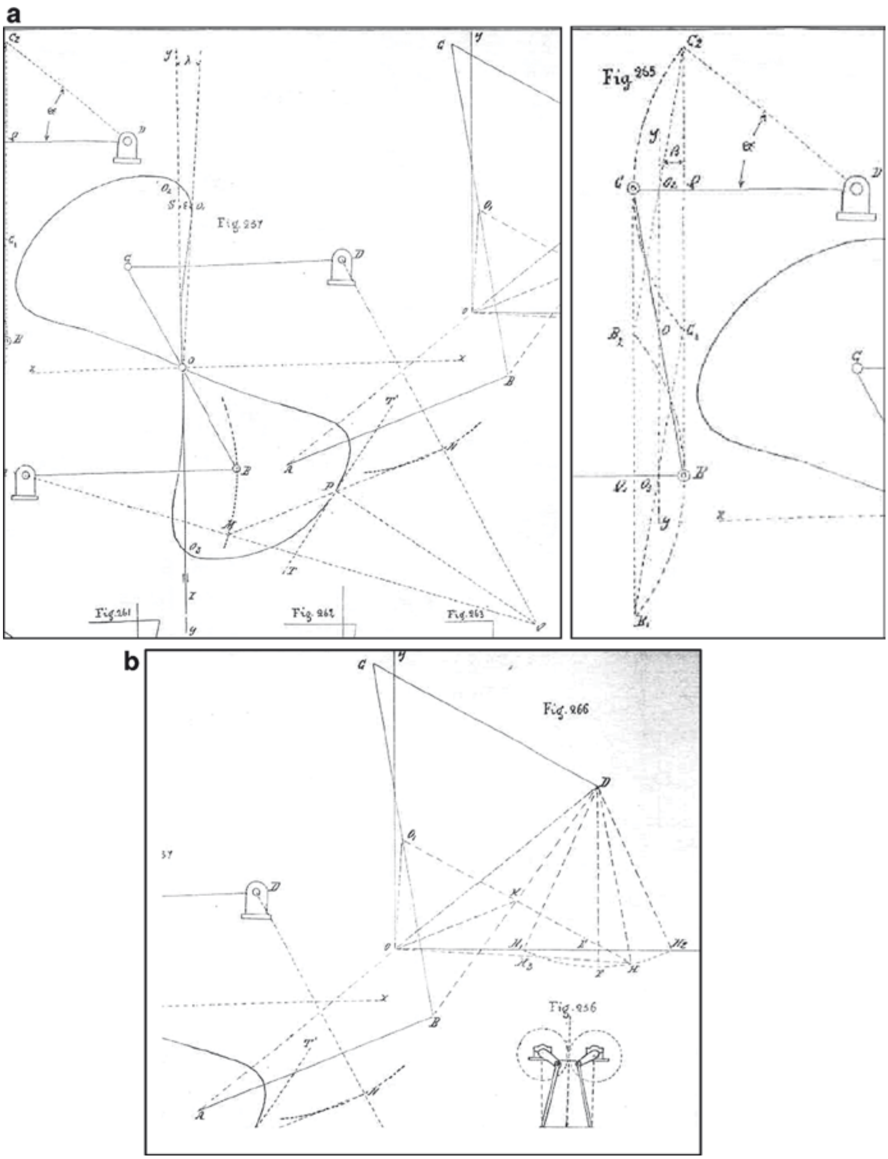

Fig. 4 Kinematic schemes for Watt parallelogram in Masi (1897a): (**a**) Figs. 257 and 265; (**b**) Fig. 266

In Fig. 7a, the case of hypoid gears is discussed by using the scheme of Figure 148 to give practical indications for a successful manufacturing and efficient use (equal normal pitches, small transmission forces, limited skew distance) and to compute the angular velocity ratio as ω_2/ω_1 after some algebraic manipulations of

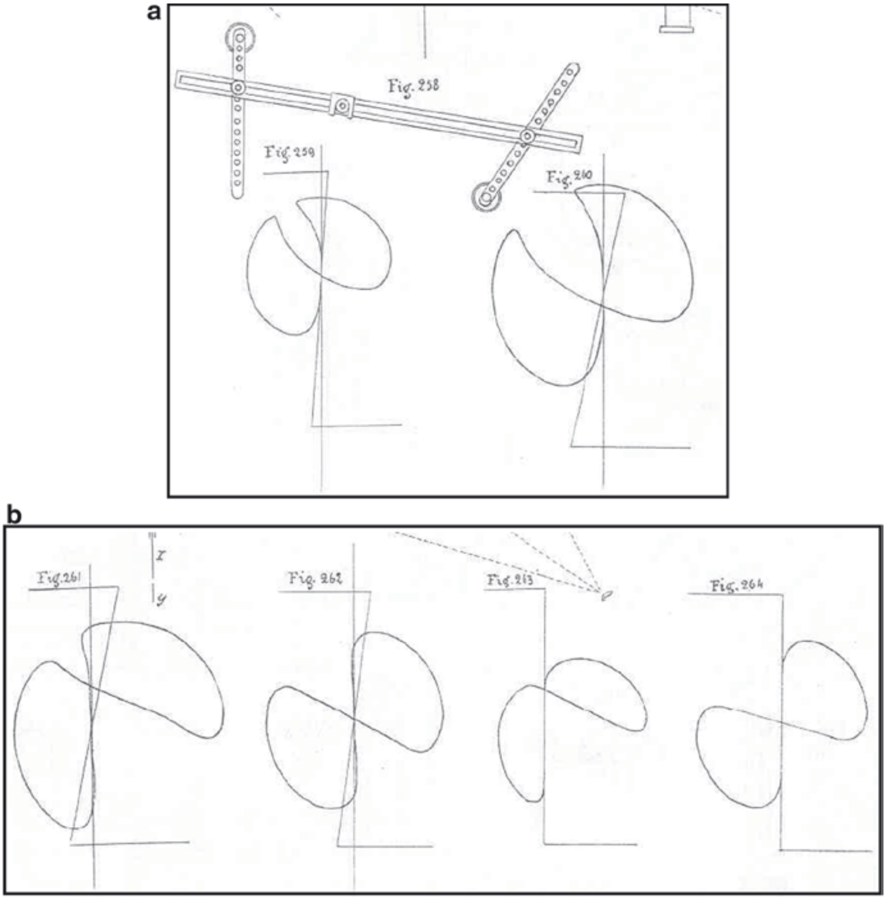

Fig. 5 A parametric study on coupler curves of the Watt parallelogram in Masi (1897a): (**a**) Figs. 258–260; (**b**) Figs. 261–264

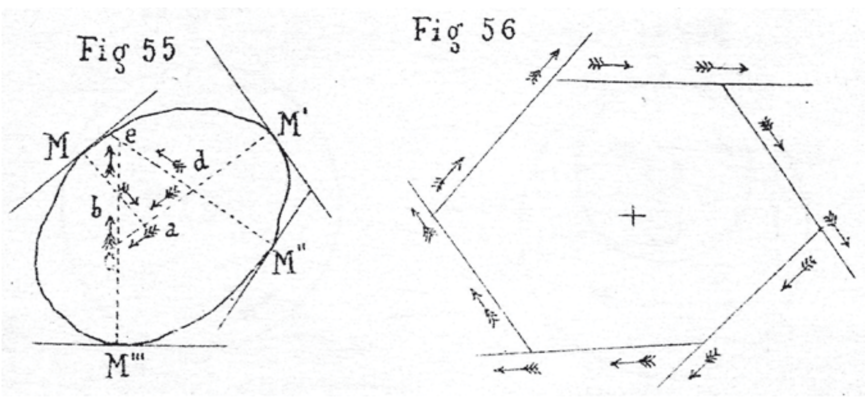

Fig. 6 Models for static analysis of multiple contacts in Masi (1897)

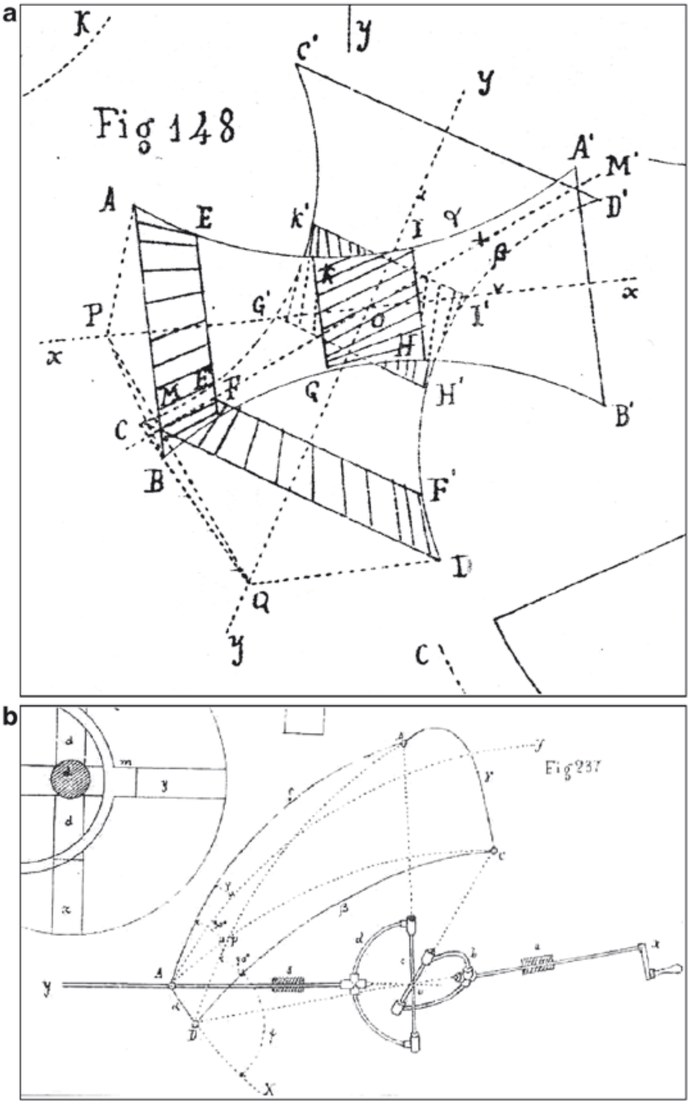

Fig. 7 Kinematic schemes in Masi (1897a) for: (**a**) hypoid gears; (**b**) Hooke's joint

the fundamental design parameters as n_1/n_2, with n_1 and n_2 as the number of teeth in gears 1 and 2, respectively.

In Fig. 7b, similarly, the Hooke joint (mainly known in Italy as the Cardan joint) is studied to characterize its kinematic operation as a function of its design parameters with formulation derivation and information for successful uses like in tower clocks, windmills, and land agriculture machinery. In particular, by referring to the scheme No. 237 in Fig. 7b, Masi deduced the well-known ration input-output in

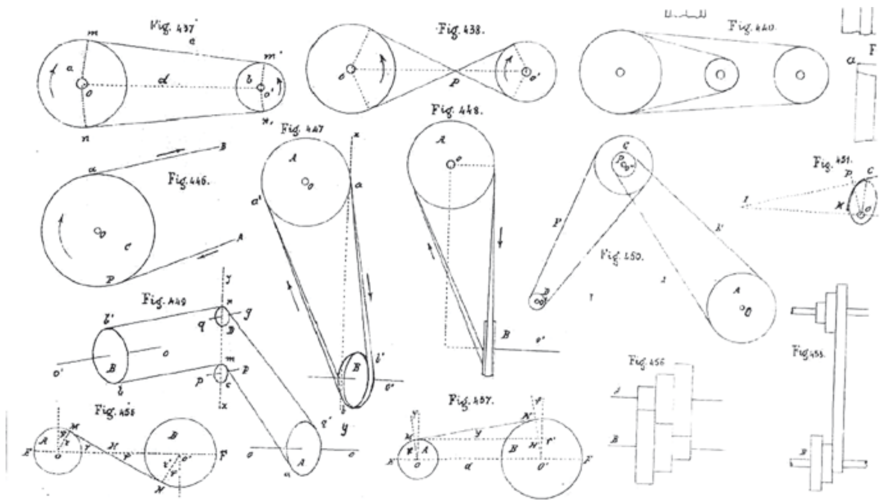

Fig. 8 Schemes and design solutions for belt transmissions in Masi (1897a)

term of cos α/(1−sin²α sin²φ) in a straightforward way by using the time derivative of geometrical expressions for the angle α among points A, O, and D and angle φ among points B, A, and Y in the structure and operation of the mechanism.

In Fig. 8, there are schemes that Masi used to describe the functionality and variety of belt systems for power transmissions. Figure 8 is an example summarizing the approach that Masi used to treat mechanisms giving theory (even trough drawings), computations, design details, and information of applications for each case. The large variety of studied mechanisms can be appreciated by the 515 schemes that he drew in his book (Masi 1897a).

It is worth noting that most of the treatments of reported mechanisms can be still considered today to be of both of theoretical/computational validity and practical interest.

Modern Interpretation of the Main Contributions

In the field of TMM, Francesco Masi made relevant contributions in a systematic approach for teaching TMM, as an historical evolution of the work by C. Giulio (Giulio 1846) in Italy and as a modern organization by following the works of R. Willis (Willis 1841) and F. Reuleaux (Reuleaux 1875). In addition, he has contributed to the scientific developments of topics regarding mechanism classification and mechanism design. The brilliant organization of the teaching on mechanisms and related theories can be appreciated in the organization of his textbooks, as outlined in previous section.

Relevant is the enhancement that Masi elaborated in Masi (1883) for the mechanism classification by using Reuleaux's approach and formalism in Reuleaux

(1875). Masi revised and completed the mechanism notation by expressing the following formalism: type symbols for general design characteristics of bodies, like for example, C is for cylinder, P is for prismatic box, R_d is for geared wheel; shape symbols for the specific geometry of the body, like for example, C^+ is for bulk cylinder (pivot), C^- is for hole cylinder (bearing), P^+ is for bulk prismatic box (slider), P^- is for prismatic guide; relationship symbols for describing the relations between two elements of a kinematic chain, like for example, || is for parallel axes, x is for crossing lines, < is for inclined lines. Therefore, any mechanism can be represented by a formula, when additional signs are used for fixed bodies (segment with dashed lines), elastic bodies (wave segment), and moving bodies (straight segment) like, for example, the cases shown in Fig. 9.

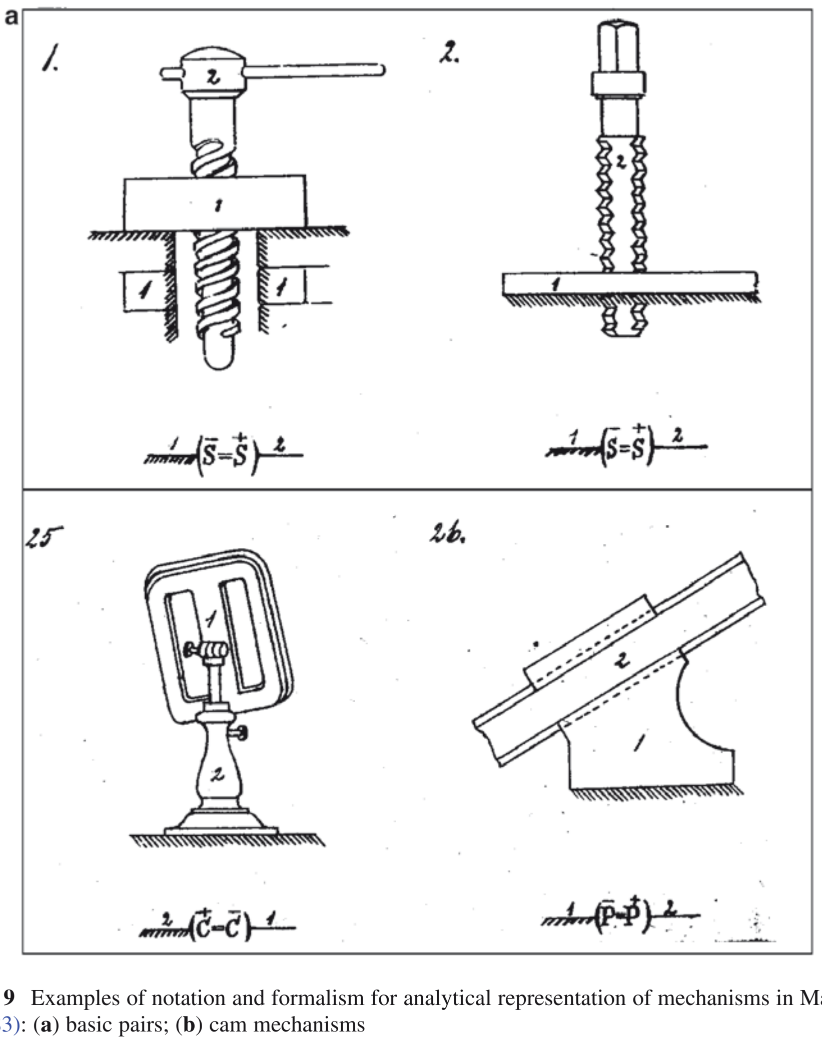

Fig. 9 Examples of notation and formalism for analytical representation of mechanisms in Masi (1883): (**a**) basic pairs; (**b**) cam mechanisms

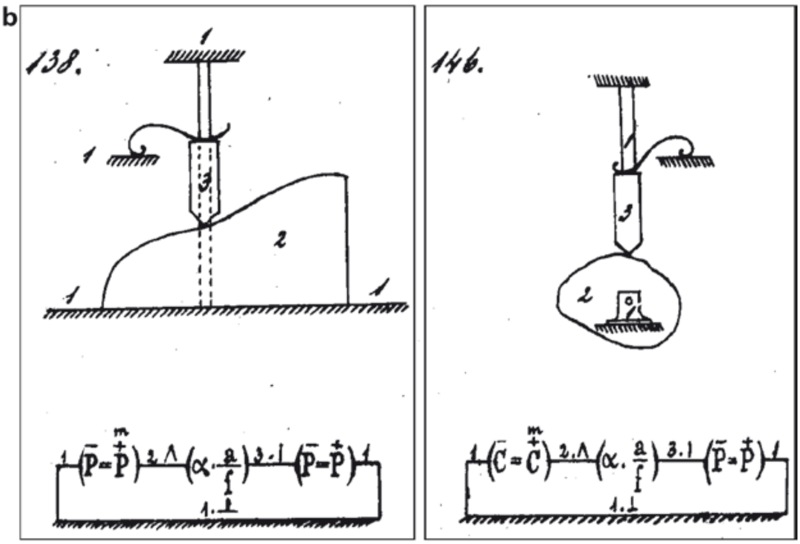

Fig. 9 (continued)

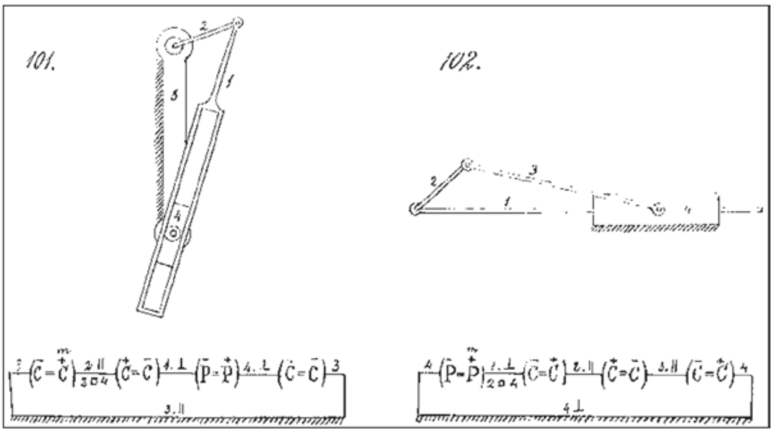

Fig. 10 Notations and schemes of mechanisms from the slider-crank chain in Masi (1883)

The notation was an attempt to develop a more analytical representation of mechanisms, avoiding encumbering mechanism drawings, even with the aim of using it for analytical treatment of the basic kinematic properties. But, as we know, it was unsuccessful because of the complexity both in writing and understanding, as the examples in Fig. 10 illustrate for the case of slider-clank mechanisms and inversions.

Some practical interest of this notation can be recognized in the definition of mechanisms by means of kinematic inversion, like the example in Fig. 10 illustrates when one considers permutation of the order of the mechanism components in choosing the frame link for the mechanism. The notation is attractive because it also can be very synthetic in showing the variety of possibilities of a kinematic chain like in the example of Fig. 11.

In addition, the formalism of the proposed notation can be considered as part of the classification rules, when one considers that the characters/rules of the classification can be expressed as functions of the introduced symbols for the fundamental kinematic properties of kinematic design of mechanisms.

Following Reuleaux's work, Masi proposed his view and formulation of mechanism classification. His view also takes into account the previous attempts of an exhaustive classification of existing mechanisms that were elaborated during the nineteenth century (Ceccarelli 2004). The basic rules of Masi's classification of mechanisms can be recognized in the concepts of simple and compound mechanisms, the kinematic chain and its inversion, categories and classes of mechanisms (Masi 1883).

Simple mechanisms are considered to be composed of one circuit of linked bodies only; compound mechanisms are those with more circuits of links with a different nature. The concept of a kinematic chain, which is the kinematic structure of mechanisms when any link is considered as a fixed frame, is useful to consider the kinematic architecture of mechanisms as mechanism topology. The kinematic inversion consists in considering any link of the mechanism as a fixed frame for different specific mechanisms as introduced by Reuleaux (1875).

A category of simple mechanisms is identified by the number of pairs of different types that are in the kinematic chain. Thus, the first category for so-called homogenous mechanisms is made of all the pairs with components of the same nature, even repeated in the chain like, for example, revolute joints or prismatic

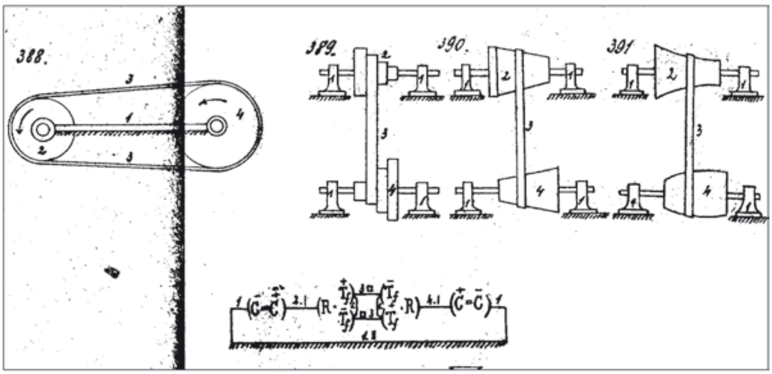

Fig. 11 Notation and schemes for a variety of belt transmissions as represented by one formula in Masi (1883)

joints, and so on. The second category for binary mechanisms is composed of two pairs of different natures, even repeated in the chain like, for example, revolute joint with prismatic guide or revolute joint with screw, and so on. Although there were a wide range of theoretical possibilities, Masi identified eight categories only, those of practical engineering interest that are made of articulation joint ($C^+ = C^-$ or $P^+ = P^-$), point with a line ($\alpha.\alpha$), two lines ($a.\alpha$), two screws ($S^+ = S^-$), two wheels (R.R), two gears ($R_d.R_d$), one gear with a pawl ($R_d.a$); compression and traction elements (with a complex notation!).

In each category, there are several possible mechanisms that can be grouped in classes with the same kinematic design. Thus, for the first category, the first class can be identified as grouping all the linkages that are composed of revolute joints (that Masi advised as the only practical ones in the category). The second class is composed of cams and wedges; the third class includes sockets; screws are in the fourth class; wheel connections are the fifth class; gears are the sixth class; the seventh class is composed of ratchets; and the eighth class is given by elements working by compression or traction.

Compound mechanisms can be classified similarly to simple mechanisms by categories and classes depending on the number of kinematic chains and their nature, respectively.

By using the above-mentioned concepts and rules, Masi classified the mechanisms according to Tables 1 and 2, by starting from the eight practical simple classes only. He advised that many of the counted mechanisms in the classes can

Table 1 Classification of simple mechanisms in (Masi 1883)

Category	Number of classes	Description of classes
Homogeneous	8	Linkages
Binary	28	Wedges and cams, sockets, screws, wheels, gears, ratchets, mechanism by traction and compression
Ternary	56	Gears with sockets, ratchets with gears
Quaternary	70	
5th	56	
6th	28	
7th	8	
8th	1	

Table 2 Classification of compound mechanisms in Masi (1883)

Category	Number of classes	Description of classes
Homogeneous	225	Compound linkages, screws, wheels, gears, ratchets, mechanisms by traction and compression
Binary	25,200	Gears and linkages, sockets and traction elements, ratchets and gears, ratchets and linkages, linkages and compression systems
Ternary	1,873,200	Same as binary
Quaternary	10,362,600	Same as binary
205th	… 1	Same as binary

be determined only theoretically (with the help of the notation!) and therefore they should be invented. Likewise, extending the consideration to more simple categories with other basic rules/structures, any other mechanisms can be invented but practical applications should be thought to be specifically part of the invention.

Thus, he applied his theory for mechanism classification by giving a unifying view of mechanisms that are also the basis of the systematic organization for teaching mechanism design. He also gave a computation of the design possibility, as reported in Table 2, in which he calculated up to 25,200 binary mechanisms and 10,362,600 quaternary mechanisms.

Regarding mechanism design, Masi clearly expressed the basic characteristics through kinematic schemes throughout his textbooks (Masi 1883, 1897a), with the aim of facilitating understanding the kinematics and the potentiality of mechanisms in practical applications.

Those comprehensive views, whose examples are illustrated in Figs. 4–8, were achieved by Masi through his encyclopedic knowledge of mechanisms that he elaborated, thanks also to his classification procedure.

Circulation of Masi's Work

Although Masi's works were very relevant and successful during his time, they were rarely considered after the Second World War. This is due mainly to two facts, namely the graphical approach and orientation of Italian users, by whom the works were written. The graphical approach was developed and greatly developed in the second half of the nineteenth century and Masi strongly used it when completed, together with some analytical formulation. But the real limitation for the circulation of Masi's work can be considered in Italian writings and orientation to the teaching in the Italian schools of engineering. This feature rapidly circulated Masi's work in Italy, mainly at the time of his career in the nineteenth century. The main orientation to Italian users can be understood when one considers that the Italian nation was only unified in 1860 and, since then, great efforts have been made to produce a common national frame for university formation.

We can consider three main topics in which Masi made relevant contributions that circulated successfully the memory of which is persistent in Italian schools of engineering, namely technical drawing for machinery, friction and early tribology, TMM and mechanism design.

Technical drawing for machinery was of great interest for technical colleges and professional activity for many years. Masi's work was considered relevant for University formation. Today, this work is addresse mainly for historical investigations on the developments of drawing technique and representations of machine elements, as indicated in Ceccarelli and Cigola (2007).

Masi's works on friction can be considered to be a significant early development of modern tribology and because of that character, they were much considered at the beginning of the Italian community on tribology. Masi's works on tribology

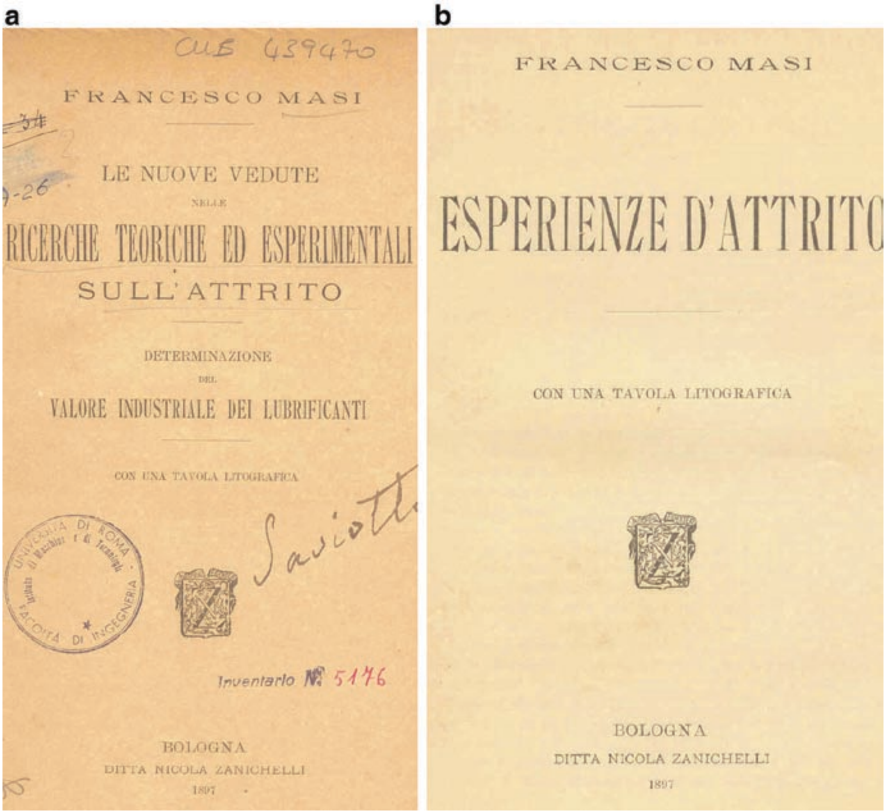

Fig. 12 Cover pages of works by Francesco Masi: (**a**) new perspectives on theoretical and experimental researches on friction in 1897b; (**b**) experiences on friction in 1897c

(Masi 1897b, c) are No.15 and 16 in the list (Masi 1927), Fig. 12, can be remembered mainly as reports of investigations.

His treatise (Masi 1897b), Fig. 12a, is a clear discussion of the state-of-arts in the field of friction evaluation that is oriented to machinery applications referring to lubrication properties. The most important theories of the time (by Petroff, Hirn, Thurstin, Kirchweger, Poiseuille) are also overviewed by referring to Italian experiences in order to propose further developments that Masi applied to practical cases for evaluation and choice of lubricant oils. An example of those results is shown in Fig. 13 also indicating the details and modernity of Masis' studies.

The experimental approach of the investigation led Masi to conceive a suitable new procedure and equipment, like the test-bed in Fig. 14 that he used to develop further knowledge of the topic of friction and lubrication, and to obtain useful results for practical engineering with determination of friction and lubrication properties as a function of environment and operation variables. Both works (Masi 1897b, c) were used even as practical handbooks on industrial engineering.

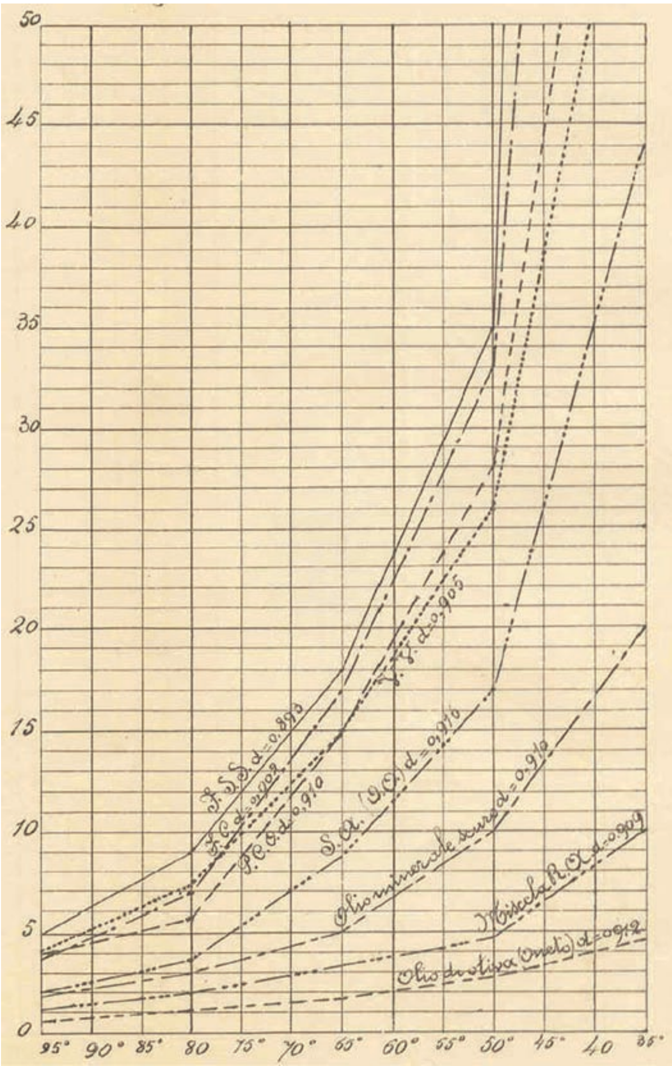

Fig. 13 Experimental results for viscosity characteristics of several lubricant oils in Masi (1897b)

However, the most successful works by Masi, also in terms of circulation, can be considered to be the books Masi (1883, 1897a) on TMM and Mechanism Design. They were used for long periods and even when they were successed by new textbooks, they were always considered as a sources of inspiration both for technical contents and conceptual explanations of mechanisms and their kinematic proprieties.

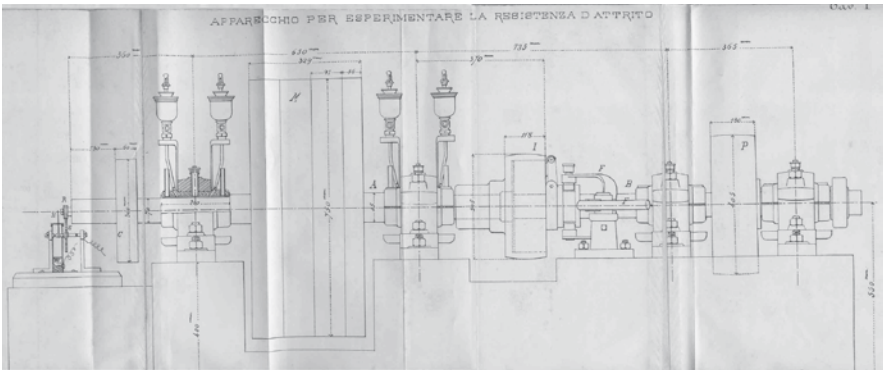

Fig. 14 Mechanical design of a new machine for friction experiments as reported in Masi (1897c)

The significance of the scientific figure of Francesco Masi is nowadays well recognized in the Italian Community for TMM but still his contributions are not know abroad, mainly because of language constraints.

The memory of Francesco Masi in Bologna is still present, even at level of current University professors. Emblematic is the story of Masi's house that he left to the School of Engineering in Bologna after his death, since he had no children to leave his proprieties to. The house, located near the School of Engineering with a nice garden, was not used for a long time and therefore it was sold in the 1950s. Today, there is great interest in having it back within the University's fold, also to recognize the personality of Francesco Masi.

Conclusions

The personality of Francesco Masi has been illustrated by emphasizing his relevant contributions in TMM that were and still are influent in the Italian Academy. Masi always developed his research activity with a vision to teaching activity and by looking at practical engineering applications, even when he encountered problems with very theoretical formulations. His work has been an inspiration for many generations in Italy and is still considered as an interesting source. Unfortunately, Masi's work is not known abroad and this paper is an attempt to refresh the memory and to point out modernity of his publications in TMM.

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