Advances in Historical Studies, 2025, 14(1), 56-78
https://www.scirp.org/journal/ahs
ISSN Online: 2327-0446
ISSN Print: 2327-0438

Interactions between Italy and Spain in the Field of Mechanism and Machine Science

Rafael López-García[1], Marco Ceccarelli[2]

[1]Departamento de Ingeniería Mecánica y Minera, University of Jaén, Jaén, Spain
[2]Laboratory of Robot Mechatronics, Department of Industrial Engineering University of Roma Tor Vergata, Roma, Italy
Email: rlgarcia@ujaen.es

How to cite this paper: López-García, R., & Ceccarelli, M. (2025). Interactions between Italy and Spain in the Field of Mechanism and Machine Science. *Advances in Historical Studies, 14,* 56-78.
https://doi.org/10.4236/ahs.2025.141004

Received: October 12, 2024
Accepted: February 11, 2025
Published: February 14, 2025

Abstract

Since long past interactions were experienced between Spain and Italy in many fields, including the technology of machines and mechanisms. This paper outlines a historical survey on exchanges by indicating to significant achievements in theory and practice of machines and mechanisms within activities also in transferring solutions, experiences, and knowledge not only within academic frames. The paper discusses up the specific interactions in modern times with the aim to present those past interactions as backgrounds and motivations for today collaboration and future joint actions.

Keywords

History of MMS, History of Mechanical Engineering, History of Mechanism Design, Distinguished Figures, Inventors, Designers

1. Introduction

Historical outlines of technical developments are usually described with a nationalist historical perspective to stress prominence and impact of a national community within considerations of broad areas in encyclopedic works as for example in Singer, Holmyard, & Hall (2012) and Capocaccia (1973), and in monographs as in Bautista, Ceccarelli, Echevarri & Muñoz (2010) and Martykanova (2023) and even in papers as in Fang & Ceccarelli (2016). One can note of these limited views also in more specific editorial works with territory promotion scopes, such as in Castell (2001) and Navascues et al. (2008). Indeed, the identity of a community with its values towards future developments can be better appreciated thanks of an awareness of the historical evolution that was also affected by external interactions and contributions (Koetsier, 2000).

This paper is an attempt to work out a new consideration of historical backgrounds for Spanish and Italian communities working in fields of Theory of Machines and Mechanisms (today MMS-Machine and Mechanisms Science), referring to aspects, experiences, and personalities that contributed to their national evolutions with mutual interaction for an international synergy over time. In addition, the paper is also aimed to attract attention to new areas of investigations such as historical-technical evaluations that can help for a better awareness of needs for internationalization of technological-scientific knowledge, with special focus on disciplines of MMS, with activities without barriers and with approaches that can broaden scopes and speed up exchange of problems and solutions for the benefit of the whole mankind.

2. First interactions in Antiquity

During the Roman Empire a common culture was promoted also to permit exchanges and fusion of people and technologies throughout its vast territory. This happened very saucerful with special activity in Europe. Thus, machine technology evolved with culture within well-established frames with design and production of several different kinds of machines in addition to war machines that all were useful for Roman legions in developing structures and infrastructures for the service of cities and army (Le Bohec, 2003; Galli & Pisani, 2009).

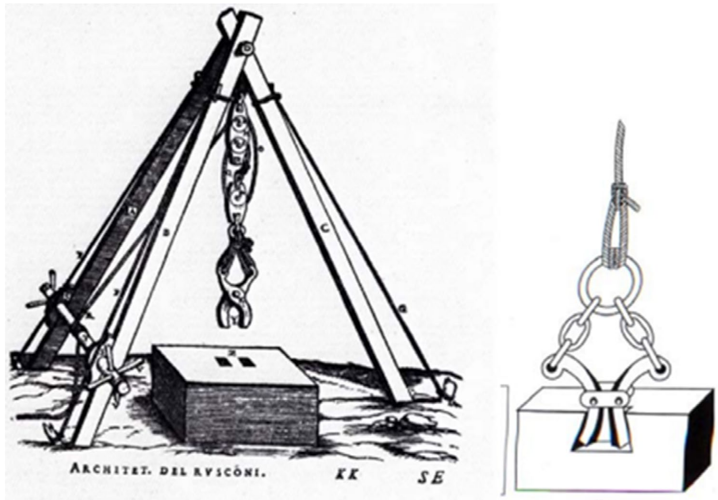
Those activities were worked out and directed by specific technicians in the legion army corps. The leader position "preprafectus fabrum" was considered a central figure for those technicians with engineer-type roles with so much reputation to be very often selected for significant social political positions thanks to a reached broad cultural vision combined with high technical expertise like the case occurred to Vitruvius nominated even consul (Cigola & Ceccarelli, 2014; Fra' Giocondo, 1511). In general, we have no life details and even names of those technician-engineers ("faber" of various specialties) who worked military service with significant contributions to the development of impactful Roman engineering. Among the many in each legion there were many from Hispania (ancient Spain). However, their activity can also be recognized in archeological details like for example in **Figure 1** that shows an archaeological finding with engineer-technician faber figures at work.

The army of the Roman Empire was organized in legions whose soldiers were ruled according to their capacities for the activities to be carried out. The skills and tasks were distributed among the legionaries so that each legion was autonomous in performing all civil and military needs, both in war campaigns and peace times (Le Bohec, 2003). The legions were composed by soldiers recruited from all regions of the empire. The Hispanic territory was one of the first to contribute as out of Italy, in so significant impact that generals and even emperors were then elected from there. Significant was also the legion soldier community in charge of technical activities for designing, constructing, and operating systems and machinery in war campaigns and in developing infrastructure and machinery for daily civil life of the surrounding civil communities.

Figure 1. A copey of a marble plate from a tomb of 2nd century B.C with a scene of Faber technicians at work on cupper tools (Courtesy of Museul of Roman Civilitation in Rome).

The legion soldier role identified by the word "faber" (builder), gives responsibility for activities in design, constructions, and management of tools and machines, using materials and means that were often available in the surrounding areas where a legion was located. From those activities experiences of exchange of knowledge and skills can be recognized in the legions in Spain or elsewhere with Spanish soldiers for the activities for a wide variety of machines, among which significant are the military ones such as ballistae, mobile assault towers, cranes, winches, wood and marble cutting machines (Rossi & Russo, 2017; Galli & Pisani, 2009). **Figure 2** shows an example of these machines as a crane and its gripping extremity tool with high theoretical and practical technological solutions, as redrawn after the rediscovery of the Vitruvius work (Cigola & Ceccarelli, 2014). Similarly, **Figure 3** shows a reconstruction of the operation of a agriculture machine based on Archimedes screw in which the power is provided by animals, although the high availability of slaves limited the development of different power sources (Ceccarelli & De Paolis, 2008).

Unfortunately, during the Roman Empire the technical activity of the "fabers", although of significant impact, was not reputed of cultural value (Ceccarelli & De Paolis, 2008), and therefore it was not reported nor recognized as personal merits for unique figures of fabers. A recognized value was attributed to those activity since Vitruvius, who with his work *"De Architectura"*, including a specific chapter on machines, (Fra' Giocondo, 1511), gave attention and cultural significance to the technical works and documents of those "faber-engineers", even with mention of some names. He also highlighted the significant impact of the technical service of the faber communities to war and civilian activities as for the development of the Roman Empire.



(a) (b)

Figure 2. Gripping with a two-finger gripper tool in roman crane applications using: (a) gripping mechanism (Fra' Giocondo, 1511); (b) internal gripping in a modern scheme (Galli & Pisani, 2009).

Figure 3. Animal power in agricultural and construction work (Fra' Giocondo, 1511).

It can be pointed out that in the legions located in Spain exchanges and collaborations among "fabers" from different nationalities and territories were experienced not only in the above-mentioned technical activities but also in training new generations of "fabers".

After the fall of the Roman Empire, ancient machine technology was forgotten together with the science achievements also after the destroy of the library of Alexandria. During Middle Ages the ancient provinces of the Roman Empire evolved into independent isolated kingdoms, and the cities re-flourished with the growth of society and economy due also to craftsmanship grouped into guilds, the bourgeoisie and trade (Castell, 2001).

In Europe a long period of isolation among the national communities was experienced up to the arrival of the Arab sultanates in Spain, who did not allow cultural and scientific-technical permeability with the Italian communities (Bautista, Ceccarelli, Echevarri, & Muñoz, 2010).

Much later, a renewed exchange activity between Spain and Italy was started by the Kingdom of Spain after the discovery of America as supporting the establishment and growth of a Spanish colonial empire by attracting and requesting technicians from different territories and particularly from Italy.

3. Exchanges in Renaissance

Significant renewed interactions between Spain and Italy were experienced during the Renaissance (Ceccarelli, 2008), mainly after 16th century when several Italians were invited to work in Spain for contributing to the technical development of the Spanish empire and colonies (Silva, 2008; Ramelli, 1588), within strategic plans for technique import and technical training policies. In that context particularly important was the *"Casa de la Contratación" (office for recruitment)* that with its scientific-technical dimension can be considered the first European governmental institution with teaching purposes and art development functions. In addition, very valuable for the time was its knowledge storage in navigation and cartography (Silva, 2008).

During the Renaissance, important technical activities were developed due to needs for increasing production and product quality so that new and renewed machines were requested in wider and wider areas in a rapidly evolving society following an expanding economy. The technological developments mainly based on machines were located in Italy and particularly in Tuscany (Silva, 2008). Quickly results and engineers (inventors and designers) spread out also to the rest of Europe and in particular to France and Spain. The powerful monarchs of the Spanish kingdoms recruited most of the engineers from Italy. The Italians arrived to Spain in great numbers, such as Juanelo Turriano, Calvi, Tercio, Sitoni, Paccioto, Leoni, Spanocchi, Locadello, Frantín, Antonelli and many others who worked in various fields of engineering. Following the experience of the Italians, even many Spanish engineers were successfully active, such as Girava, Lastanosa, Esquivel, Morales, Rojas, Montalbán, Lobato and Ayanz, among many others (Silva, 2008). The exchanges towards Spain were particularly significant, also in the opposite direction, thanks to relations of Italian territories with the Kingdom of Spain and especially the Bourbon Kingdom of the two Sicilies in southern Italy. Significant part of those exchanges was motivated by the growing development of the Spanish colonial empire with activities of exploitation and development of the South American colonies.

An outstanding example of this period can be considered Juanelo Turriano, whose Italian name was Gianello Torriani (1500-1585), who worked out significant activity for design and construction of various types of machines, especially in the field of hydraulic engineering and agricultural production (Pseudo-Turriano, 1570?). Born in Verona, he met Charles I when he was crowned emperor in Bologna. In that occasion he received an astronomical clock that Giovanni de Dondi had built in 1364. He was asked to repair the clock, but Juanelo proposed to build a new one. Thus, started a relationship with Charles I until his death in the monastery in Yuste. Juanelo continued the service at the Spanish kingdom with the successor Philip II. Juanelo designed various mechanical devices, such as clocks, automatons, and other machines, but his most outstanding work can be considered in hydraulic engineering with devices and systems for raising water. Famous still today is the complex one designed and built for raising water at high quote difference from the Tajo River to Toledo city, which has given rise to many studies, analyses and even reproductions in scale.

The established tradition of exchanges was confirmed during the following centuries and at certain moment particularly directed to the south of Italy in the ancient kingdom of the two Sicilies that was linked to Spain by the king families.

Another example of the Italian-Spanish interactions is the case that was generated in those territories when the need appeared with increasing demand for diving apparatus to search for corals, pearls, and sunken treasure ships. Reference figure of these activities at that time was Giuseppe Bono, who travelled from Italy to Spain in the mid-16th century to test new diving bells, although without success, as coming from several ideas and attempt in Italy. Later the Spanish Jerónimo de Ayanz designed an autonomous diving device, being the first solution with a valve. He tested his diving device successfully in the Pisuerga River in 1602, so that he obtained an exclusive license to manufacture and operate it in 1606. These design activities caused disagreements between the two designers up to reach at legal levels with a lawsuit.

Giuseppe Bono was active also in other fields and in 1580 in Spain he invented and designed a centrifugal regulator system as in **Figure 4** for mills. The system is powered by animals to move the long bean of the first gear axis as described in the manuscript in the General Archive of Simancas (Castell, 2001).

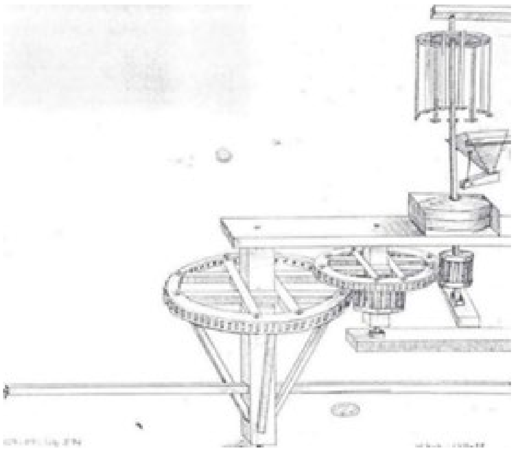


Figure 4. A centrifugal regulator invented in 1580 by Giuseppe Bono (Castell, 2001).

A curious case of technology transfer from Italy to Spain was that with the Venetian captain Domingo Varonier, who came to Spain with his son to present the secret of the manufacture of Murano glass for which he was given a privilege of invention in Spain in 1607.

These Italian-Spanish relations in the field of MMS also had many controversies such as the emblematic example referring to the treatise "*Los veinte y un libros de los ingenios y las máquinas de Juanelo*" (Castell, 2001). Apparently Juanelo Turriano was commissioned by the King to write it. But later modern analysis and studies of the treatise show that he could not have been the author, because in the treatise there are mentions to specific places where he never visited. In addition, the Spanish writing and style with abundant Aragonese expressions seems not be congruent with his Spanish language skills. Additionally, he does not even allude to his main design of water pumping system in Toledo (Spain). All of the above leads to believe that the author could be none other than the Aragonese Pedro Juan de Lastanosa (Garcia Tapia & Carrillo Castillo, 2002), who at that time was able to design new solutions like the one in **Figure 5**, which refers to a weight-powered mill patented by him and which coincides with the one that appears in the aforementioned treatise.

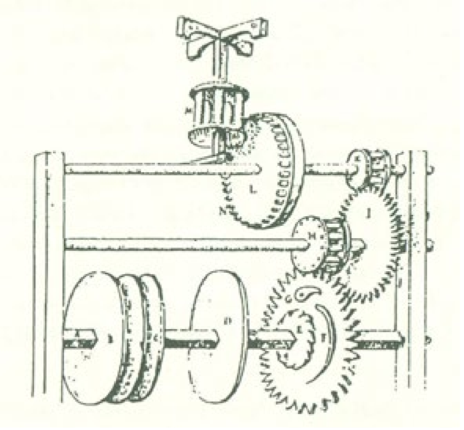


Figure 5. Weigh-powered mill in the treatise "*Los veinte y un libros de los ingenios y las máquinas*" (Castell, 2001), coinciding with the patent of Pedro Juan de Lastanosa (Garcia Tapia & Carrillo Castillo, 2002).

It was Jerónimo Girava (?-1556), cosmographer to Charles I, who also designed all kinds of navigational instruments, and he even wrote a treatise on hydraulic engineering. During a trip accompanying the emperor through Aragonese lands he met Lastanosa and, as impressed by his qualities, recruited him as pupil. By accompanying Girava, Lastanosa travelled to Flanders and later in 1556 to Naples for a commissioned hydraulic engineering work. On the way to Milan, Girava died and Lastanosa continued his journey without his master. He had the chances to get in contact with the effervescent spirit of modernity and renaissance of classical antiquity in Italy. In Naples he was involved in various hydraulic works and in 1563 Philip II recruited him into his service as a *"machinist and master builder of* *fortifications"* (Garcia Tapia & Carrillo Castillo, 2002).

During the 16th century, great efforts were spent on finding new sources of energy to replace animal power. One such source was the gravitational energy of weights, which was already well known, especially in its application to watchmaking. These efforts are another example of Italian-Spanish technical interactions. Already in the 14th century, Milanese technicians managed to move small "clockwork" mills with this mechanical system, although they were of insufficient power for grinding grain. In 1571, the Italian Alessandro Barsoquini claimed to have designed a counterweight mill that could grind as much grain as water mills. But when the monarch asked him to demonstrate his invention, it seems that he was unable to make it to work. However, Lastanosa succeed with a design of a counterweight mill, for which the king granted him a privilege for its operation in 1569, although not without controversy. The Spanish engineer Ruy López de Luna claimed to have invented such a mechanical system before and to have shown it to Lastanosa asking collaboration in its examination. But, according to him Lastanosa got the privilege of operation without sharing it (Garcia Tapia & Carrillo Castillo, 2002).

It was at this time that Juan de Herrera (1530-1597) began to be well recognized as an architect and scientific-technical advisor to the King, due to his territorial and family influences. He accompanied the King on his "most felicitous journey" through Flanders, Germany and Italy, during which he must have met Juanelo Turriano in Milan, who was working on the construction of some astronomical clocks for the emperor. He later joined the Tertiaries army and took part in the campaigns of Siena and Piedmont with an experience that he used for his later work on geometry and architecture. He used the geometric figure of the circle as a basis for his explanation of machines, particularly cranes, in his work *"Arquitectura y máquinas"*. In architecture, his main work was related to El Escorial king house with activities to design also the necessary machinery, like the crane in in **Figure 6.** One of the most notable machines invented by Juan de Herrera with the

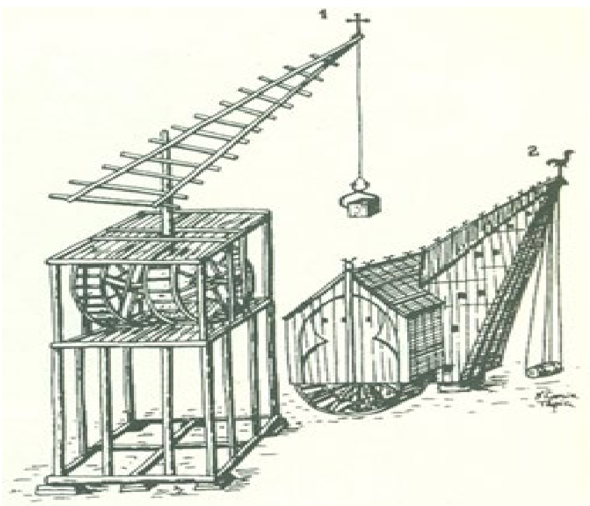


Figure 6. El Escorial crane attributed to Juan de Herrera, compared to a medieval port crane (López, 1979).

Flemish engineer Leonardo Xupi was a device for cutting iron into small pieces. He also contributed to the design of the most famous machine of the time, namely the pumping system to raise water from the Tajo River to Toledo., that was designed by Juanelo Turriano.

However, we cannot speak of the figure of royal architects as such until the arrival of Juan Baustista de Toledo, who came directly from Naples as well formed in the best Renaissance style of the Italian Antonio Sangallo and Michelangelo (Garcia Tapia & Carrillo Castillo, 2002).

The 16th century also saw the translation of several Italian treatises on machines, such as the summary or adaptation of the Vitruvius works in a book entitled *"Medidas del Romano",* that was written by Diego de Sagredo in 1526, a cleric who lived in Italy for some time. An early Spanish version of Vitruvius' work was also published by the bookseller Juan Gracián in 1582. Similarly in that period other treatises were published as translation of Italian treatise on architecture and mathematics.

Other significant works with significant machine designs at the time were those to make the rivers navigable, although opposed in some extent from owners of the hydraulic mills. The Italian Juan Bautista Antonelli developed successfully works in 1582 to navigate from Lisbon to Madrid.

Also, of Italian origin is Jácome Trezzo, a close friend of Juan de Herrera, who was the inventor of several devices for sawing and cutting jasper, marble and other hard materials.

Among other interesting inventions of the time, it is worth highlighting the one presented by Jerónimo de Ayanz in 1606 referring to the first industrial applications of steam energy, almost a century ahead of those of Savery, which marked the beginning of the English Industrial Revolution, based on the use of the steam engine (Castell, 2001).

Other Spanish engineers worked in Italy in military fields when accompanying the campaigns, as for example did Diego de Vera and Pedro Navarro at the beginning of the 16th century, assisting the great captain in Castelnovo, Garellano or Gatea, or Luis Collado de Lebrija, by working as "engineer of the army of Lombardy and Piedmont". Thanks to this activity he is author of one of the first treatises on artillery, the first version of which was translated in the Italian language in 1586.

The reputation of Italian engineers in designing fortifications was also a reason for their influence in Spain even with their recruitment. From 1559 the Bolognese Francisco Marchi worked in the service of Philip II, and later he was joined by the Italian Tiburcio Spanochi and Juan Bautista Antonelli. Some Spanish engineers worked with them, such as Cristóbal de Lechuga, a disciple of Juan de Herrera, who was the king's engineer and taught fortification at the Academy of Mathematics at the beginning of the 17th century (López, 1979).

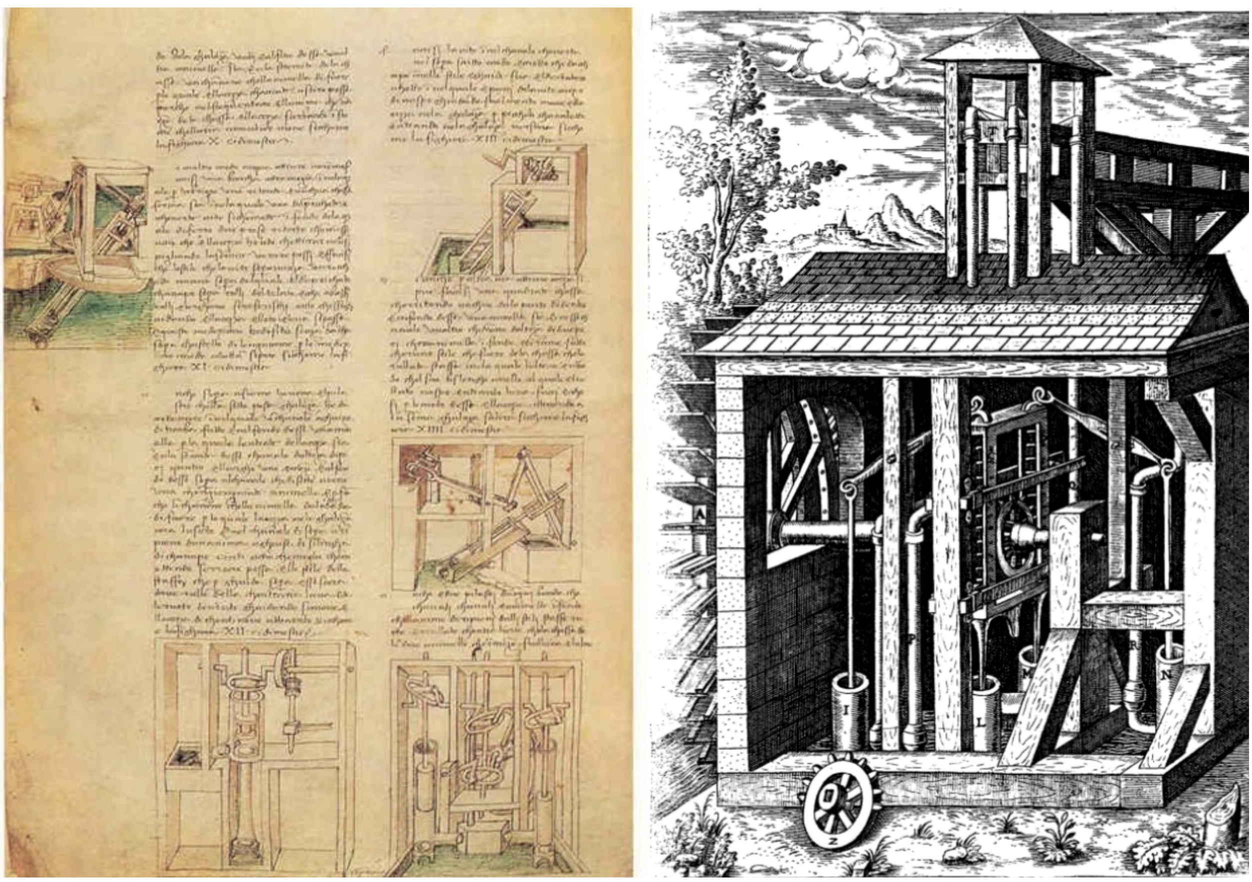
Another aspect has facilitated and promoted the dissemination of techniques and development of machines from Italy not only to Spain, is related to manuals or treatises on machines, the first of which can be attributed to Francesco di

Giorgio Figure 7(a) (Ceccarelli, 2008) published in 1482, so successful that was soon copied in several versions. Figure 7(a) shows different design of pumping systems with different mechanism accompanied with a text for explaining the design structure and operation

These early treatises later reached a production in print with a much wider diffusion and with translations into Spanish as for example, the treatise by Agostino Ramelli Figure 7(b) (Ramelli, 1588) published in 1588, that was a reference also for the later technical manuals on machines (Theatrum Machinarum).

Moreover, this first production of technical literature was also used in wider cultural spheres, as for example by the Jesuits in the evangelization missions of the communities in the South American and Asian colonies (Ceccarelli & Zhang, 2022). This transfer of technological knowledge promoted also first universities in South America such as San Marco in Peru and Havana with a recognized academic background in machines following the pioneering example of Galilei (Ceccarelli, 2006).

Beside wide dissemination of the Italian works, Spanish contributions of the 16th century were also translated into other languages or reprinted in other countries, as shown by the fact that there were 206 Spanish scientific works on machines,



(a) (b)

Figure 7. (a) Illustration of different pumps from Francesco di Giorgio's treatise (Ceccarelli, 2018); (b) A machine design in the treatise by Agostino Ramelli (Ramelli, 1588).

i.e. more than a quarter of the total subjects, reaching the important figure of 1226 foreign editions (López, 1979).

It was during the Renaissance that the regulation of inventions began, with the first patents being granted in the Italian states in the second half of the 15th century, albeit for a limited territory. Just later the first patents were granted in Spain for a wide territory, which was even extended to new territories with the discovery of America.

Italian-Spanish relations were so important at that time that it became necessary a dictionary for translation of technical terms. In 1570 the *"Vocabulary of the two Tuscan and Spanish languages"* was published by the Spanish humanist Cristóbal de las Casas (1530-1576) as a first reference of technical terminology in MMS, that was properly elaborated only in 1970s' by IFToMM (IFToMM, 1991).

4. Developments during Industrial Revolution

At the beginning of the Industrial Revolution in Italy and Spain there were not significant developments of industrialization as in other European countries. This started slowly later especially because of the political and economic situations in the countries. In short, this delay happened in Italy because of the efforts for national unification and in Spain for a decline of the colonial empire with local effects as well.

Nonetheless, the accumulation of skills and experiences in the previous centuries produced an incubation which subsequently gave rise to a significant industrialization with mainly internal contributions since there was no exchange between Italy and Spain if not for reasons of political ties. During the Industrial Revolution, technologies were developed for the use of new energy sources in industry, such as steam engines, gas or diesel engines, and later electricity, which replaced, with few exceptions, hydraulic and wind energy in powering industrial machines and mechanical devices, such as the widely used mills (Silva, 2005).

In the centuries preceding the Industrial Revolution, Spain addressed attention entirely to the South American colonies, not only in economic aspects, but also with the objective of technological developments that would make the distant colonies even more autonomous. Spain joined the industrialization process later than other countries due to various reasons, such as the fact that there was no previous agrarian revolution, there was a great technological backwardness, the country's economy was ruined due to the War of Independence that brought a poor demographic growth and the return to absolutism that did not favor industrialization. With these factors, it was difficult to achieve a real industrial take-off, although this could gradually become viable in peripheral regions or areas such as Catalonia, that is favored by easy access to the sea, making possible to avoid inland routes.

In Italy, after national unification, government plans and favorable economic and political conditions have stimulated the development of an industry starting from local realities with visions of a wider national market (Scalera, 2011; De Rosa, 1968). In fact, it can be observed that a significant industrialization in areas distributed throughout the country took place above all in the second part of the nineteenth century but with activities with very rare interactions with Spain. In Italy all through the 19th century, educational and technical efforts were addressed to standardize social and productive aspects over the national territory. This reduced interest and activities in technological exchanges in cooperation with other countries. Thus, during the period of Industrial Revolution, the limited interactions between Italy and Spain gave results that are difficult to identify with prominent figures, although exchanges and collaboration were experienced with certain continuity, also because of political ties between Spain and the many states in Italy before unification.

In Spain, the flourishing Royal Factories established in the previous century gave significant impulse with also reforming activities that accompanied development of industrial realities of significant entrepreneurs also at European level, (López-García, 2006).

A strong industrial collaboration between Spain and Italy was active mainly before the Italian unification, mainly through experiences and developments of royal factories as based on the connections of the Spanish royal house with the royal house of the kingdom of the two Sicilies. The Royal Factories were created in the 18th century by the Bourbon kings with forerunner aspects of today's public enterprises. Their establishment and work were panned as part of industrial development policy of the enlightened despotism with aim of starting domestic industrial activities under the royal control. They were organized by mimicking the French "Manufactures Royales", that were created by Jean-Baptiste Colbert (1619-1683), Minister of Finance of Louis XIV, during the 17th century. Among the objectives one can recognize aspects to strengthen the absolutist state, to increase tax revenues, to develop industry as strategic defense of self-sufficiency, especially in luxury goods (textiles, glass, coins, playing cards, tobacco, porcelain, tapestries, watches, machinery, weapons, metallurgy, etc.). These royal factories were organized of two types, namely those founded by the Kings and those from existing factories that were granted of this category.

As examples, we can cite the Royal Coin Factory (Turismo de Segovia, 2024) in Segovia, Spain, and the Royal Factory of Pietrarsa (Ceccarelli, 2014) in Naples, in Italy. The Pietrarsa Factory is also interesting since very probably workers and engineers were recruited in exchange interactions with common shared technical training, although there is no documentation remained for the secrecy of a political nature as well as for the loss of archives due to past and recent devastations in war situations. The Royal Coin Factory of Segovia in **Figure 8(a)** was commissioned by King Felipe II in 1583 and it was designed by the royal architect and scientist Juan de Herrera (1530-1597), in collaboration with Juanelo Turriano (Gianello Torriani). It can be considered a factory with first original skills in mechanism design in Spain.

The Royal Coin Factory in Segovia was designed to work out the entire process for metal coin production, namely from the raw material up to the final coin production. The process was based on a lamination and minting system by means of different machines that were powered by hydraulic wheels on the nearby river, Figure 8(b). The process was evolved from the traditional hammer stamping process as in Figure 9(a) common in the past centuries in many other European cities. The hammer coin production was replaced in 1771 by the flywheel press in Figure 9(b) with characteristics that motivated further evolution of the technology in the mid-nineteenth century by designing and using automatic presses as in Figure 9(c). They were installed and used in the Segovia factory until 1869 (Turismo Segovia, 2024).

In South Italy during the first half of nineteen century significant industrial developments can be pointed out in the metallurgic factory network of Reali Ferriere, Officine di Mongiana and Fonderia Ferdinandea, with a production of high quality and quantity that successfully was appreciated all around Europe. This metallurgy production was also a fundamental basis for the Royal Factory in

(a) (b)

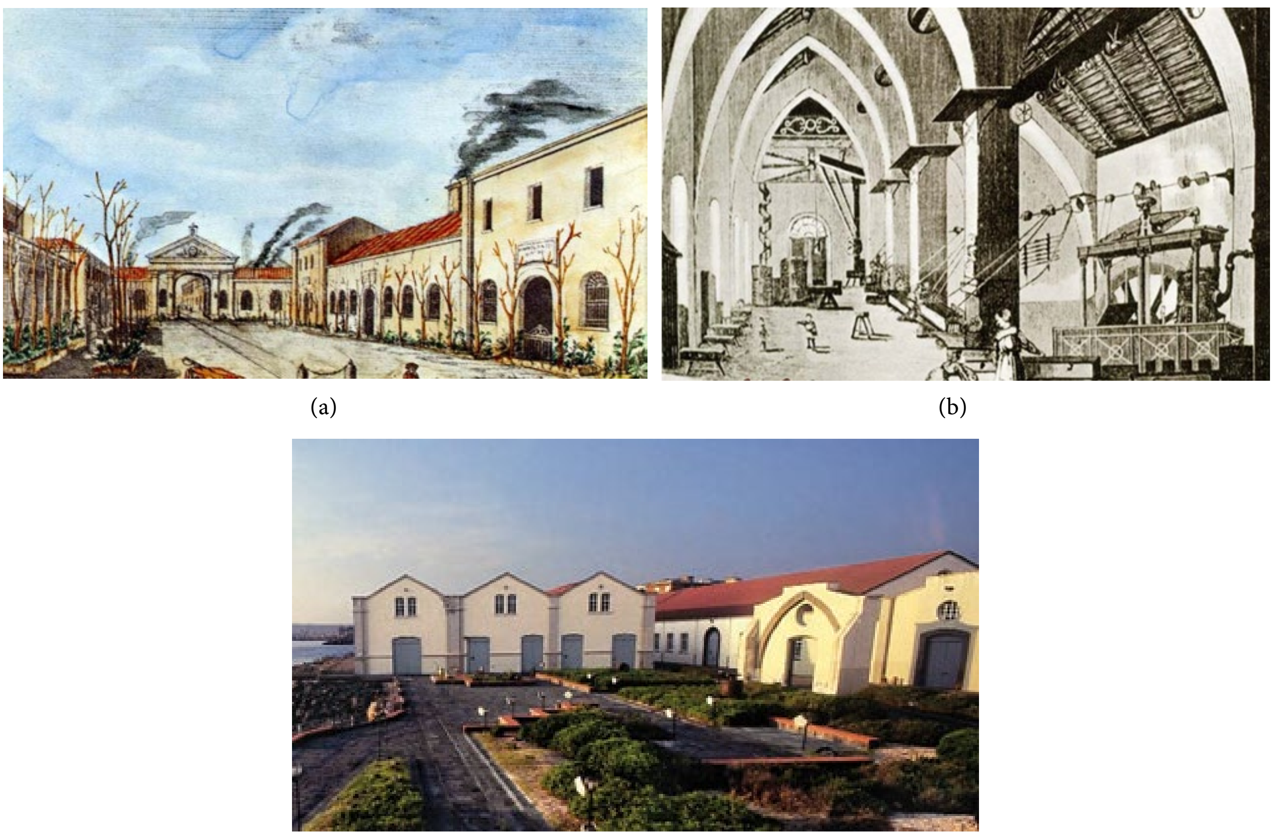
Figure 8. A view of the Royal Coin factory in Segovia in Spain: (a) overall building; (b) the power station with hydrulic wheels.

(a) (b) (c)

Figure 9. Coin productions: (a) by hammer manual operation; mer press; (b) by flywheel press (c) by hydraulic lamination and minting process.

Pietrarsa (Rossi & Ceccarelli, 2012; Fang & Ceccarelli, 2015), **Figure 10**, that was established and worked successfully for the development of railway system of the kingdom, even with original designs of locomotives. The Royal Factory in Pietrarsa, was commissioned by the king Ferdinando II at the beginning of the 1830s and immediately after was well developed with a significant production and a considerable number of employees, including a center for technical formation. Those development activities were supported with contributions of Spanish engineers and workers, who were attracted to the industrial initiatives as also based on a strong relation between the kingdom of the Two Sicilies and the Bourbon kings, although during the Industrial Revolution the flows of people were mainly directed towards the new centers of technological growth such in northern Europe. The Royal Factory in Pietrarsa, grew to give work to more than over 1,000 workers, and Spanish technicians certainly contributed. However, it is not possible to document specific figures due to the loss of the factory archives that occurred both after the unification of Italy and as a result of its destruction during World War II (Fang & Ceccarelli, 2015).

An important figure of the period in this Italy-Spain relationship for an early Industrialization at the beginning of 19the century can be recognized in Carlo Filangieri (1784-1867) (Ceccarelli, 2023), **Figure 11(a)** who was a promoter and



(a) (b) (c)

Figure 10. A view of the Royal Factory in Pietrarsa, near Naples in Italy: (a) from a painting at its start; (b) internal plant of mid 1800s; (c) todays.

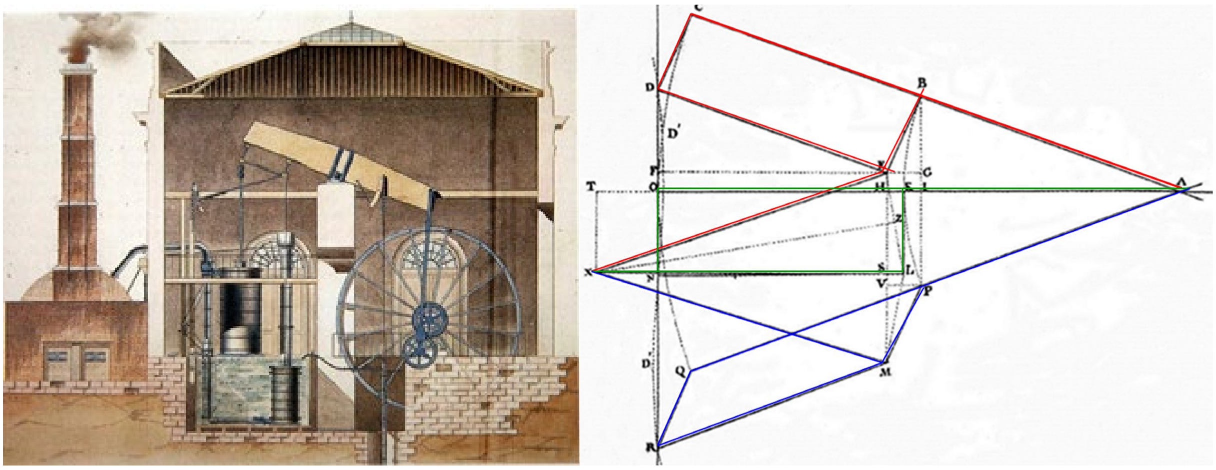
(a) (b)

Figure 11. Portrait of: (a) Carlo Filangieri (Ceccarelli, 2023); (b) Agustín de Betancourt y Molina (Cuadrado, 2007; Cuadrado, 2018).

political supporter of the factory, although he never directly participated in the direction of the Royal Factory in Pietrarsa. The Royal Factory in Pietrarsa, produced several types of machinery at its beginning and later, since the end of 1830s' was dedicated to the design and production of railway material and in particular locomotives up original designs (Rossi & Ceccarelli, 2012; Fang & Ceccarelli, 2015).

During the Industrial Revolution in the first half of the 19th century the most significant developments in the technological field occurred in the British Kingdom and in the academic scientific frames in France with later transfers to all of Europe, generating further dissemination of new original achievements worldwide. Many technical personalities went to these areas of Europe for their training and formation in new technologies, as was the case of Agustín de Betancourt y Molina (1758-1824), (Cuadrado, 2007; Cuadrado, 2018; Ceccarelli, 2023), **Figure 11(b)**, who, born in the Canary Islands, travelled through France, England, and Russia, where he visited factories and came into contact with new machines and mechanisms, among others with the steam engine. He gave important contributions in developments of mechanical engineering, besides in TMM, in Spain and Russia where he lived up to death establishing Russian frames of engineering, (Ceccarelli, 2023).

He worked pioneering studies and designs on theory and practice of mechanism design, with great impact in the engineering developments worldwide. An early example is the design procedure that he proposed in 1789 in "Mémoire sur une machine à vapeur à double effet" (Iglesias & Ceccarelli, 2024) referring to kinematic synthesis of Watt mechanism in a double-acting steam engine, **Figure 12**. More famous is the "Essai sur la composition des machines" of 1808, written together with José María de Lanz, under the guidance of Gaspard Monge (Cuadrado, 2007; Cuadrado, 2018; Ceccarelli, 2023), since it can be considered the first modern treatise on mechanism design with an exhaustive classification of mechanisms based



(a) (b)

Figure 12. Design of the Watt mechanism in double-acting steam engine by Agustín de Betancourt in 1789, (Iglesias & Ceccarelli, 2024): a) the whole steam engine; b) a scheme of 3 precision pints synthesis.

on the motion transmission. This had a great impact in engineering field through the whole 19th century being translated in many languages and it was considered source for further investigations and classification of mechanism topologies and designs. As for that and for his very successful career, he was a reference not only for the Spanish frames in teaching and research activities for many decades.

Those two examples are indicative of the fruitful activity of interactions that from Spain-Italy frames were expanded in more international frames starting a vision of mechanical engineering without political barriers.

After the unification of Italy from 1870, interactions with Spain ceased not only due to the change in the political structure relative to the Italian kingdom of Savoy, but mainly due to government programs aimed at standardizing the social, economic and technological frames of the Italian territory. Although at a personal and family levels, the interactions with Spain were continued even if not with the same the intensity and impact during the first half of the 19th century. Thus, it is more difficult today to recognize documented personalities and experiences of that past.

5. Collaborations in Modern Time

In modern times, collaboration and exchange between Italy and Spain are mainly based on personal contacts that nevertheless most of the time are promoted by institutional programs for internationalization and cooperation in teaching and research frames. Recently that national based cooperation is further stimulated within the European community whose international programs reinvigorate personal relationships.

In the academic field, since after the 1960s interactions between Spain and Italy have been and are still constant, even being reinforced through the Erasmus program, that since 1990 has permitted consolidation and expansion of pre-existing institutional bilateral agreements for teaching and training activities for students and teachers within the educational levels (bachelor, master, and doctorate). The Erasmus program permits sharing also courses of various academic curricula in addition to mechanical engineering, and successful is also available for joint activities and supervisions of theses and internships. In the last decades, several Italian and Spanish universities regularly shared these activities, even within multiple-institution agreements. Results of these activities are produced in relevant production in teaching material, theses, and internship reports available from the involved academic entities.

Spanish-Italian interactions in research activities have been and are still organized within projects that are planned by local, national, and international programs, with funding by the European community and by national and regional organizations and institutions. They usually give significant results in quantity and quality as also demonstrated by publications in proceedings of national and international conferences, and in journals of different editorial impact, as well as by monographs and co-authored books. Scientific collaborations is worked out in all the areas of mechanical engineering with an expansion of interests in several disciplines of MMS giving significant results in papers co-authored from different generations of Spanish and Italian scholars with reinforced actions of collaborations.

In the last decades, collaborations and exchanges have been also promoted successfully in the frames of the international societies and federations such as IFToMM (International Federation for the promotion of the science of machines and mechanisms), and FEIBIM (Ibero-American Federation of Mechanical Engineering). Even national societies pay important roles not only within the national territory since collaboration and visibility abroad is included in this mission, like for the AEIM (Spanish Association of Mechanical Engineering) and the IFIT (IFToMM Italy). In addition, technical commissions on specific subjects of current or visionary interests are planned with activities organized within these societies and federations to promote and run activities for further development of different fields of mechanical engineering. Those technical commissions with active representant from Spain and Italy work out activities considering also attention of the historical aspects of the fields. Specific committees are also organized on the specific field of History of MMS are organized with planned activities to track the history of the fields looking at figures of inventors and scientists and their achievements in theory and practice, and to investigate and disseminate worthful results from the history of mechanical engineering and particularly of machines and mechanisms. In these activities and committees Italian-Spanish interactions are particularly efficient in supporting results with expansion to multinational collaboration.

Significant result of these recent collaborations in the fields of History of mechanical engineering are books on distinguished figures in mechanical engineering with a successful attention and promotion also from editorial frames. Significant are the books on distinguished figures in Spain, Italy, and Latin America: *"Figuras Ilustres de la Ingeniería Mecánica en España"*, **Figure 13(a)** (López-

García & Bautista, 2018), and *"Figuras Ilustres de la Ingeniería Mecánica en España e Iberoamérica"*, **Figure 13(b)**, (López-García & Bautista, 2020) that are published by the Editorial of the University of Jaén within a series of History of Engineering. A revised expanded version of these books are also published in English by the international publishing house Springer such as *"Distinguished Figures in Mechanical Engineering in Spain and Ibero-América"* **Figure 13(c)** (López-García & Ceccarelli, 2023), as a proof of international interests of this type of publication within the successful series on the History of the Science of Machines and Mechanisms. The above-mentioned books are results of a long-time collaboration coordinated by the authors, as significant example of Italian-Spanish interactions in the field of History of machines and mechanisms.

In addition, the reciprocal participation in the Italian and Spanish national conferences on MMS is significant during many decades with a growing number of contributions, even in co-authorship. Examples can be pointed out referring to the last conference events of the Spanish National Congress of Mechanical Engineering CNIM-2021, **Figure 14(a)** (López-García et al., 2021), held in Jaén, and the Italian Conference of IFToMM Italy IFIT-2022, **Figure 14(b)** (Niola, Gasparetto, Quaglia, & Carbone, 2022) held in Naples. Following these events with the planned frequency, in the next conference in 2024 and 2025 in Italy and Spain, respectively, even specific sessions are planned on Spain-Italy collaborations.

The successful collaboration and appreciation of the Italian and Spanish communities is reinforced by organizing and cooperating for joint events such as summer schools, international conferences and Symposiums in different universities, alternatively in the two countries. Significant examples with very impactful

(a) (b) (c)

Figure 13. Covers of books on History of Mechanical Engineering referringi to distinguished figures: (a) (López-García & Bautista, 2018); (b) (López-García & Bautista, 2020); (c) (López-García & Ceccarelli, 2023).

results with published proceedings well circulated worldwide can be indicated in the European Conference on Mechanism Science EUCOMES-2012 held in Santander, Figure 15(a) (Viadero & Ceccarelli, 2023), followed in 2024 by EUCOMES2024

(a) (b)

Figure 14. Titlepages of the national conference proceedings: a) the Spanish CNIM in 2021, (López-García et al., 2021); b) the Italian IFIT in 2022 (Niola, Gasparetto, Quaglia, & Carbone, 2022).

(a) (b) (c)

Figure 15. Titlepages of the international conference proceedings: a) EUCOMES-2012 (Viadero & Ceccarelli, 2023); b) HMM-2022 (Ceccarelli & López-García, 2022); c) I4SDG-2021 (Quaglia, Gasparetto, Petuya, & Carbone, 2021).

in Padova, 7th International Symposium on History of Machines and Mechanisms (HMM-2022), held in Granada and Jaén, **Figure 15(b)** (Ceccarelli & López-García, 2022), the IFToMM for Sustainable Development Goals (I4SDG-2021), held in Turin, **Figure 15(c)** (Quaglia, Gasparetto, Petuya, & Carbone, 2021), followed in 2023 by I4SDG-2023, held in Bilbao (Petuya, Quaglia, Parikyan, & Carbone, 2023).

The above editorial significant results as examples of a very productive collaboration between the today Italian and Spanish communities in MMS show that there are well-established exchange and collaborative interactions between Italian and Spanish institutions that are nevertheless based on interests and activities of individuals who yet give sure further development collaboration within the science and technology of machines and mechanisms with participation of new generations of students, researchers, and teachers.

6. Conclusion

This paper presents a historical account of the developments of the science of machines and mechanisms in Italian-Spanish collaborative frames in descriptive approach different from usual nationalist studies with the aim to outline the historical description with influence from external communities. In addition, the paper aims to show the importance of contaminating exchanges and interactions in technologies and solutions with experiences, works and research generating successfully synergies that do not consider and overpass any kind of barriers.

Common aspects in Italian and Spanish cultures come from antiquity during the Roman Empire so to establishing a strong interaction between Italian and Spanish societies that have expanded up to technological fields with transfer of technology and people during the Renaissance, the Spanish colonial empire, the Industrial Revolution, up todays. Modern collaborations are reinforced in academic and research frames with activities that are largely channeled and promoted by national and international associations through meetings, events, conferences, projects, and institutional and personal relationships.

The authors are aware that this paper is not exhaustive in cataloguing and describing the Italian-Spanish interactions and collaborations in the field of the science of machines and mechanisms over the time. Besides giving hints on aspects and figures in a large window of time, the paper reports results of historical-technical investigations on the history on technical relations in both directions, from Spanish "engineers" to Italy, and from Italian "engineers" to Spain. In this sense, possible future work could be planned to improve research and analysis of distinguished figures and engineers, their achievements and inventions, the period during which they were active within the state of the art at that time. This kind of work can contribute to awareness for understanding and recognition of significance of mechanical engineering and particularly of machines and mechanisms over time with no limited nationalist views.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

Bautista Paz, E., Ceccarelli, M., Echavarri Otero, J., & Muñoz Sanz, J. J. (2010). *A Brief Illustrated History of Machines and Mechanisms*. Springer. https://doi.org/10.1007/978-90-481-2512-8

Capocaccia, A. (1973). *History of Technique—From Prehistory to the Year One Thousand*. UTET. (In Italian)

Castell, G. A. et al. (2001). *Historia de la Tecnología en España* (Vol. I, II). Valatenea, S.L.

Ceccarelli, M. (2006). Early TMM in Le Mecaniche by Galileo Galilei in 1593. *Mechanisms and Machine Theory, 41,* 1401-1406. https://doi.org/10.1016/j.mechmachtheory.2006.02.005

Ceccarelli, M. (2008). Renaissance of Machines in Italy: From Brunelleschi to Galilei through Francesco di Giorgio and Leonardo. *Mechanism and Machine Theory, 43,* 1530-1542. https://doi.org/10.1016/j.mechmachtheory.2008.01.001

Ceccarelli, M. (2014). An Italian Landmark in Machine Developments at the Beginning of Industrial Revolution. In *CD Proceedings on IFToMM Workshop on History of MMS* (p. WHMMS-3). Tianjin University.

Ceccarelli, M. (2018). Contributions of Francesco di Giorgio in Mechanism Design. *Anales de Ingeniería Mecánica, 21,* 352-362.

Ceccarelli, M. (2023). Carlo Filangieri (1784-1867). In R. López-García, & M. Ceccarelli (Eds.), *Distinguished Figures in Mechanical Engineering in Spain and Ibero-America (History of Mechanism and Machine Science, Vol. 43)* (pp. 91-106). Springer. https://doi.org/10.1007/978-3-031-31075-1_4

Ceccarelli, M., & De Paolis (2008). A Brief Account on Roman Machines and Cultural Frames. In *Proceedings of HMM2008—The Third IFToMM International Symposium on History of Machines and Mechanisms* (pp. 83-100). Springer. https://doi.org/10.1007/978-1-4020-9485-9_7

Ceccarelli, M., & López-García, R. (2022). *Explorations in the History and Heritage of Machines and Mechanisms (History of Mechanism and Machine Science, Vol. 40)*. Springer. https://doi.org/10.1007/978-3-030-98499-1

Ceccarelli, M., & Zhang, B. (2022). Contributions of Italian Jesuits in Machinery Technology Transfer to China in the 16-18th Centuries. In V. Niola, *et al.* (Eds.), *Advances in Italian Mechanism Science* (pp. 7-15). Springer. https://doi.org/10.1007/978-3-031-10776-4_2

Cigola, M, & Ceccarelli, M. (2014). Marcus Vitruvius Pollio (Second Half of the 1st Century B.C.). In M. Ceccarelli (Ed.), *Distinguished Figures in Mechanism and Machine Science—Part 3* (pp. 307-344). Springer. https://doi.org/10.1007/978-94-017-8947-9_15

Cuadrado Iglesias, J. I. (2007). Agustín de Betancourt y Molina (1758-1824). In M. Ceccarelli (Ed.), *Distinguished Figures in Mechanism and Machine Science (History of Mechanism and Machine Science Vol. 1)* (pp. 31-60). Springer.

Cuadrado Iglesias, J. I. (2018). Agustín de Betancourt y Molina (1758-1824). In R. López-García, & E. Bautista-Paz (Eds.), *Figuras ilustres de la Ingeniería Mecánica en España* (pp. 58-84). Editorial UJA.

De Rosa, L. (1968). *Iniziativa e capitale straniero nell'industria metalmeccanica del mezzogiorno 1840-1904*. Giannini & Figli.

Fang, Y., & Ceccarelli, M. (2015). Peculiarities of Evolution of Machine Technology and Its Industrialization in Italy during 19th Century. *Advances in Historical Studies, 4,* 338-355. https://doi.org/10.4236/ahs.2015.44024

Fang, Y., & Ceccarelli, M. (2016). Medium Size Companies of Mechanical Industry in Northern Italy during the Second Half of the 19th Century. In *Essays on the History of Mechanical Engineering (History of Mechanism and Machine Science, Vol. 31)* (pp. 181-200). Springer. https://doi.org/10.1007/978-3-319-22680-4_11

Fra' Giocondo (1511). *De Architectura by Marcus Pollione Vitruvius* (M. Vitruvius per Iocundum solito castigator factus cum figuris et tabula…). Venetiis.

Galli, M., & Pisani, S. G. (2009). *Machina—Tecnologia dell'antica Roma*. Palombi Editori.

Garcia Tapia, N., & Carrillo Castillo, J. (2002). *Tecnología e imperio, ingenios y leyendas del siglo de oro*. Nivola.

IFToMM (1991). IFToMM Commission A. Standard for Terminology. *Mechanism and Machine Theory, 26,* 435-539. https://doi.org/10.1016/0094-114X(91)90002-L

Iglesias, J. I. C., & Ceccarelli, M. (2024). Betancourt Synthesis for Three-Position Problem in Mechanism Design. In *History of Mechanism and Machine Science* (289-302). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-54876-5_21

Koetsier, T. (2000). Mechanism and Machine Science: Its History and Its Identity. In *Proceedings of HMM2000 International Symposium on History of Machines and Mechanisms* (pp. 5-24). Kluwer Academic Press. https://doi.org/10.1007/978-94-015-9554-4_2

Le Bohec, Y. (2003). *The Roman Army*. Carocci Publ.

López Piñero, J. L. (1979). *Ciencia y técnica en la sociedad española de los siglos XVI y XVII.* Editorial Labor, S.A.

López-García, R. (2006). *Molinos hidráulicos. Apuntes de historia y tecnología*. Editorial Formación Alcalá, S.L.

López-García, R. et al. (2021). *Anales de Ingeniería Mecánica*. Año 22.

López-García, R., & Bautista-Paz, E. (2018). *Figuras Ilustres de la Ingeniería Mecánica en España*. UJA Editorial.

López-García, R., & Bautista-Paz, E. (2020). *Figuras Ilustres de la Ingeniería Mecánica en España e Ibero-América*. UJA Editorial.

López-García, R., & Ceccarelli, M. (2023). *Distinguished Figures in Mechanical Engineering in Spain and Ibero-América (History of Mechanism and Machine Science, Vol. 43)*. Springer. https://doi.org/10.1007/978-3-031-31075-1

Martykanova D. (2023). *Los ingenieros en España*. Editorial de la Universidad del País Vasco.

Navascues, Córdoba de la Llave, R. et al. (2008). *Ars Mechanicae. Ingeniería medieval en España*. Ministerio de Fomento CEDEX-CEHOPU. Fundación Juanelo Turriano.

Niola, V., Gasparetto, A., Quaglia, G., & Carbone, G. (2022). *Advances in Italian Mechanism Science. Proceedings of the 4th International Conference of IFToMM Italy* (Vol. 122). Springer. https://doi.org/10.1007/978-3-031-10776-4

Petuya, V., Quaglia, G., Parikyan, T., & Carbone, G. (2023). *Proceedings of I4SDG Workshop 2023. I4SDG 2023. Mechanisms and Machine Science* (Vol. 134). Springer. https://doi.org/10.1007/978-3-031-32439-0

Pseudo-Turriano, J. (1570?). *Los veinte y un libros de los ingenios y las máquinas*. Manuscrito existente en la Biblioteca Nacional.

Quaglia, G., Gasparetto, A., Petuya, V., & Carbone, G. (2021). *Proceedings of I4SDG Workshop 2021. Mechanisms and Machine Science* (Vol. 108). Springer.

https://doi.org/10.1007/978-3-030-87383-7

Ramelli, A. (1588). *Le diverse et artificiose machine*. Paris.

Rossi, C., & Ceccarelli, M. (2012). Heavy Industries in Southern Italy before the Unification. *CD Proceedings on IFToMM Workshop on History of Machine and Mechanism Science*, Palermo 21-22 November 2012, University of Palermo.

Rossi, C., & Russo, F. (2017). *Ancient Engineers' Inventions. History of Mechanism and Machine Science* (Vol. 33). Springer. https://doi.org/10.1007/978-3-319-44476-5

Scalera (2011). *I grandi Imprenditori del XIX secolo: Centocintuant'anni di storia di italia di scoperte, di invenzioni, di impresa, di Lavoro*. CEDAM.

Silva Suarez, M. (2005). *Técnica e Ingeniería en España: III-El Siglo de las luces* (Vol. I). Real Academia de Ingeniería Institución Fernando el Católico, Prensas Universitarias de Zaragoza.

Silva Suarez, M. (2008). *Técnica e Ingeniería en España: I-El Renacimiento. De la Técnica Imperial y la popular* (Vol. I). Real Academia de Ingeniería Institución Fernando el Católico, Prensas Universitarias de Zaragoza.

Singer, C., Holmyard, E. J., Hall, A. R., & Williams, T. I. (2012). *History of Technology* (Vol. 2). Bollati Boringhieri. (In Italian)

Turismo de Segovia (2024). https://turismodesegovia.com/es/casa-de-moneda

Viadero, F., & Ceccarelli, M. (2023). *New Trends in Mechanism and Machine Science. Theory and Applications in Engineering, Mechanisms and Machine Science* (Vol. 7). Springer.