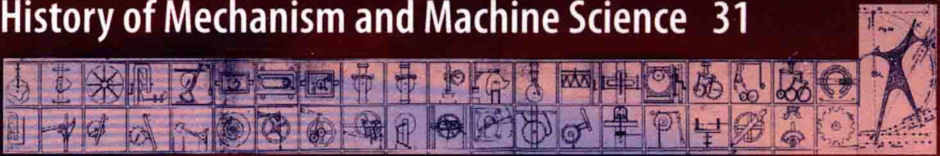
History of Mechanism and Machine Science 31



Francesco Sorge
Giuseppe Genchi *Editors*

Essays on the History of Mechanical Engineering

Springer

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ISSN 1875-3442 ISSN 1875-3426 (electronic)
History of Mechanism and Machine Science
ISBN 978-3-319-22679-8 ISBN 978-3-319-22680-4 (eBook)
DOI 10.1007/978-3-319-22680-4

Library of Congress Control Number: 2015951518

Springer Cham Heidelberg New York Dordrecht London

Printed on acid-free paper

Springer International Publishing AG Switzerland is part of Springer Science+Business Media
(www.springer.com)

History of Mechanism and Machine Science

Volume 31

Series editor

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Preface

The twelfth PC Workshop on the History of Mechanism and Machine Science (MMS) was held at the Polytechnic School of the University of Palermo, Italy, in November 21–22, 2013, under the patronage of the IFToMM. It was organized by Profs. Marco Ceccarelli, Francesco Sorge, Marco Cammalleri, and Giuseppe Genchi and was hosted inside the Museum of Engines and Mechanisms of the University of Palermo, whose director and chief manager, F. Sorge and G. Genchi, respectively, are the editors of this book.

All workshops of the IFToMM Permanent Commission for the History of Mechanism and Machine Science are organized as limited-circle meetings with the aim of promoting the presentation of unpublished material and stimulating new interest in various historical developments in the fields of Mechanism and Machine Science. They want to open debates on many aspects associated with the birth and growth of mechanisms and machines from antiquity up to the present day: kinematics, dynamics, design methods, collections of models, teaching aids, historical biographies, individuals, institutions, etc. The first of these workshops was held in Admont, Austria, in 2002, and was followed nearly annually by eleven further meetings with parallel objectives. The focus of the 2013 HMMS Workshop in Palermo was, in particular, on the European History of Mechanism and Machine Science.

The idea of the present book originated after the workshop out of the desire to give a complete and extensive form to the abstracts that were proposed on that occasion. Most of these abstracts were turned into extended papers by the attending authors, collecting the information given in their oral presentations and enriching their work with new data and results from the ensuing historical researches. After acceptance from a review process, the extended papers were then distributed into separated parts of the book, collecting them in accordance with their themes, in which each paper constitutes, in practice, a chapter of the book and each section refers to a particular aspect of the history of mechanisms and machines.

- Part I is dedicated to several eminent scientists of the past, whose individual contributions may be considered as milestones in the history of MMS. In particular, this part offers a deep insight into certain advancements brought to scientific knowledge by renowned scholars such as Lagrange, Borgnis, Reuleaux, Ovazza and Frolov.
- Part II illustrates relevant aspects of the wide industrial development that has so deeply been involved in European civil life during the last two centuries. In particular, very interesting chapters are presented on various types of ancient mill installation in Abruzzo and Tuscany in Central Italy; on the sulfur mining industry of the nineteenth and twentieth centuries in Sicily; on the aviation industry in Romania at the beginning of the twentieth century; on the industrial progress in Southern Italy before the unification of the Kingdom of Italy and in Northern Italy before and after the unification.
- Part III concerns the history of machinery for fixed and moving application, and the history of transport in general. It addresses the pioneering development of technology in the field of motors and transport, and presents, in respective chapters: the collection of the Museum of Engines and Mechanisms of Palermo; the history of an ancient Spanish railway; and the devising of the first airships of the nineteenth century.
- Part IV is dedicated to human creativity in the field of mechanical and scientific devices, starting from ancient times up to the last century. The subjects cover machines built during the Renaissance on the basis of ancient designs of the Roman period; the bellows devices operated by falling water in use in the forges of the Middle Ages and the Renaissance; pendulum clock development through the centuries; the screw pumps conceived in Central Italy by Guido Ubaldo Del Monte at the dawn of the Renaissance; and the progress in the measurement methods for the shaft torsional stress state.
- Part V deals with several ingenious machines dating from the remote and recent past, all designed with the aim of relieving or replacing human manual work or setting in motion very huge structures. Starting from antiquity, very heavy carts are described in detail, together with their construction technique, the so-called Rathams or Thers, which were brought in procession by human and animal traction in ancient India. Moreover, operation of an automaton of the Hellenistic period is analyzed, which moved up and down upon a procession cart and had to be probably actuated by special mechanisms. Lastly, a survey is given on the history of robots in general, including some recent examples that were devised and built at the Polytechnic University of Milan near the end of the last century and are now exhibited in the Museum Leonardo da Vinci in Milan.

As mentioned in the brief description of Part III, the book contains a chapter on the Museum of Engines and Mechanisms of Palermo, in which collections of historical pieces are briefly described with the aid of a number of illustrative figures. The museum belongs to the museum system (Sistema Museale di Ateneo-MUSEIUNIPA) of the University of Palermo, together with the museums of Zoology, Geology, Radiology, the "Specola," or Astronomic Observatory, and the

Botanical Garden. It was inaugurated in February 2011 and collects more than three-hundred items testifying to the development of the mechanical sciences in the last one hundred and fifty years of history. Its contents cover the fields of automotive and aircraft engines, stationary engines, hydraulic machines, laboratory, and didactic devices. Just to mention a few examples, we recall the following: the FIAT G.59 trainer aircraft of the 1950s, which has been recently restored by the Museum and represents one of the five remaining specimens in the world; the radial steam turbine Ljungstrom of the old electric power plant in Palermo; a rare Siemens Halske IIIa bi-rotary aero-engine, the crankshaft, and crankcase of which counter-rotated with opposite angular speeds. All the pieces were taken from the storerooms of the former Institute of Machines and were revived thanks to a scrupulous work of restoration, accompanied by careful historical research. The Museum is our own pride and the pride of the University of Palermo. Many scientific events have been hosted there, and many others are continuously programmed. Its choice as the venue for the twelfth PC Workshop on the History of Mechanism and Machine Science fit quite well with the themes of the meeting and it is hoped that other similar events will take place there in the future.

To sum up, despite the limited number of contributions, this volume shows a wide-ranging panorama on the historical progress of scientific and technical knowledge, mainly in the European environment. Hopefully, it may give new stimuli to all people involved in the history of Science and Technology.

Finally, the editors wish to express their gratitude to all people who have given their valuable contributions to this editorial project, and in particular, they thank all the authors and co-authors of the chapters for the enthusiasm they have put in preparing their admirable essays. Special thanks are devoted to the editorial staff of Springer for their helpful co-operation. Moreover, the editors owe a warm acknowledgment to their friend, Professor Marco Ceccarelli, for his precious suggestions during the groundwork and preparation of this book and for his assistance during the editorial process.

Palermo
December 2014

Francesco Sorge
Giuseppe Genchi

Contents

Part I
Eminent Scientists of the Past

Lagrange as a Historian of Mechanics

Agamenon R.E. Oliveira

Abstract In the first and second parts of his masterpiece, Analytical Mechanics, dedicated to static and dynamics, respectively, Lagrange (1736–1813) describes in detail the development of both branches of mechanics from a historical point of view. In this paper, Lagrange's important contribution (Lagrange 1989) to the history of mechanics is presented and discussed in tribute to the bicentennial year of his death.

1 Introduction

Lagrange was one of the founders of variational calculus, through which he derived the Euler-Lagrange equations. He also developed the method of Lagrange multipliers, which is a manner of finding local maxima and minima of a function subjected to constraints. He developed the method for solving differential equations known as the parameter variation method. In addition, he applied differential calculus to the theory of probabilities and did notable work in obtaining the solution of algebraic equations. Furthermore, in calculus, Lagrange introduced a new approach for the interpolation of the Taylor (1685–1731) series. His famous treatise known as the Theory of Analytical Functions contains the path that leads to the foundation of group theory, anticipating the work of Evariste Galois (1811–1832).

In mechanics, Lagrange studied specific problems, such as the three-body problem related to the motion of the earth, sun and moon. By means of his Analytical Mechanics, he transformed Newtonian mechanics (Newton 1952) into a branch of analysis, Lagrangian mechanics, which was a result of the application of variational calculus to mechanical principles. Through this work, rational

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F. Sorge and G. Genchi (eds.), *Essays on the History of Mechanical Engineering*,
History of Mechanism and Machine Science 31,
DOI 10.1007/978-3-319-22680-4_1

mechanics was able to fulfill the long-desired Cartesian aim of becoming a branch of pure mathematics.

In relation to problems later called applied mechanics, Lagrange, in the works known as the Mélanges de Turin, studied the propagation of sound, making an important contribution to the theory of vibrating strings. He used a discrete mass model to represent string motion consisting of n masses joined by weightless strings. Then, he solved the system of n + 1 differential equations, when n tends to infinity, to obtain the same functional solution proposed by Euler (1707–1783). Lagrange also studied the integration of differential equations and made various applications to topics such as fluid mechanics, for which he introduced the Lagrangian function.

Lagrange's Analytical Mechanics was published in 1788, crowning a series of works and other important contributions previously developed by d'Alembert (1717–1783) and Euler (1952). This book presents a model of formalized theory with the same meaning that is now understood by modern physicists. The logical unity of this theory is based on the least action principle. However, the two dimensions of formalization and unification are the main characteristics of Lagrange's method.

2 Lagrange: A Biographical Note

Joseph-Louis Lagrange was born in Turin on January 25, 1736, under the name of Giuseppe Lodovico Lagrangia (Fig. 1). His father, Giuseppe Francesco Lodovico Lagrangia, was Treasurer of the Office of Public Works and Fortifications in Turin. His mother was Teresa Grosso, the only daughter of a medical doctor from Cambiano near Turin. Lagrange was the eldest of their eleven children, but one of only two to live to adulthood.

Turin became the capital of the kingdom of Sardinia in 1720, sixteen years before Lagrange's birth. His family had French connections on his father's side. His grandfather was a French cavalry captain who had left France to work for the Duke of Savoy. For this reason, Lagrange always leant towards his French ancestry. When he was young, he signed his name Lodovico LaGrange or Luigi Lagrange, using the French form of his family name.

Lagrange's interest in mathematics began when he read a copy of Halley's 1693 work on the use of algebra in optics. He was also attracted to physics by the excellent teaching of Francesco Ludovico Beccaria (1716–1781) at the College of Turin, leading him to decide to follow a career in mathematics.

Mécanique Analytique was written by Lagrange during his period in Berlin and was approved for publication by a committee from the Academy of Sciences consisting of Laplace (1749–1827), Cousin, Legendre (1752–1833) and Condorcet (1743–1794). This book summarized all the work done in the field of mechanics since the time of Newton (1642–1727), being notable for its use of the theory of differential equations. In 1810, Lagrange commenced a thorough revision of his

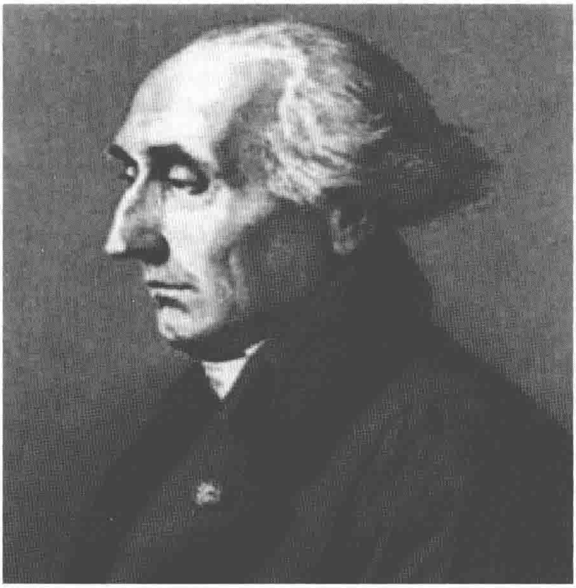

Fig. 1 Joseph-Louis Lagrange (1736–1813)

masterpiece, but he was able to complete only about two-thirds of it before his death in Paris on April 10, 1813. He was buried in the same year in the Panthéon in Paris. The French inscription on his tomb reads:

> Joseph-Louis Lagrange. Senator. Count of the Empire. Grand Officer of the Legion of Honour. Grand Cross of the Imperial Order of the Reunion. Member of the Institute and the Bureau of Longitude. Born in Turin on 25 January. Died in Paris on 10 April 1813.

3 Science and the French Revolution

The French revolution has great importance as a fundamental transformation of European society from the social, political and scientific viewpoints. Besides the intellectual and cultural changes before the takeover of power by the bourgeoisie in France, with direct consequences for scientific production over a long period of Lagrange's history, we should also mention other factors and aspects of this context.

The first important thing to note is the need of the new regime for new institutions in order to criticize and fight against the ideas of the *ancien regime*. These new institutions also appeared within the educational system as the best way to change mentalities and to prepare new technical and political elite to give continuity to the project of a new society announced by the Revolution.

The transformations in the educational system of France implied significant modifications in technical and professional education, because new creeds, new knowledge and new technologies had emerged, making it necessary to teach them. The development of engineering and its teaching is important in this context. A reformation of engineering instruction was also necessary because war with other European countries had stimulated the construction of fortifications, roads and bridges, and the development of artillery. This new context propelled France to apply scientific principles to industry, with the result that the new engineering had to provide universal scientific knowledge, as well as tools and methods applicable to a diverse range of practical situations (Belhoste 2003). As we know, Lagrange played an important role in the context of these transformations. He was the first professor of analysis, appointed for the opening of the *École Polytechnique* in 1794. In 1795, the *École Normale* was founded with the aim of training school teachers. Lagrange taught courses on elementary mathematics there.

4 Historical Considerations in *Analytical Mechanics*

4.1 First Part: Statics

Lagrange began his history of statics by defining this discipline associated with the concept of force. He states:

> Statics is the science of forces in equilibrium. We think, in general, of force or power as a cause, anything that impresses or tend to impress motion on the body under consideration; it is also by the quantity of impressed motion, or by its tendency, that a force or power must be estimated.

According to him, the objective of statics is to provide the laws that govern equilibrium. In this sense, equilibrium appears as the destruction of several forces that oppose and annihilate them. These laws are based on three general principles, namely: (a) the equilibrium of the lever; (b) the composition of motions; (c) virtual velocities. It is, thus, in the context of the historical development of these three principles that Lagrange rebuilds the history of statics.

Lagrange considers Archimedes (287–212 B.C.) to be the only scholar from ancient times to produce a theory of Mechanics, which is contained the latter's two books entitled *Aequiponderantibus*. Archimedes was also the author of the principle of the lever (Dijksterhuis 1987). In modern times, the contributions of Stevin (1548–1620), in his Statics, and Galileo (1564–1642), in his *Dialogues* (*Discorsi*) about motion, had transformed Archimedes' demonstration into a much more simple and useful concept (Galileo 1988). However, it seemed to Lagrange that ancient mathematicians did not know of a method for generalizing the principle of the lever to other simple machines, notably the inclined plane. This problem was also posed to the first modern mathematicians. Stevin presented the first exact solution to this problem independent of the lever theory. These considerations led him to the impossibility of perpetual motion (See *Elements of Statics and Hypomnemata Mathematica*.).