Ce Zhang · Jianming Yang

A History of Mechanical Engineering

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ISBN 978-981-15-0832-5 ISBN 978-981-15-0833-2 (eBook)
https://doi.org/10.1007/978-981-15-0833-2

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

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Chapter 1
Introduction

With copper as a mirror, you can dress up.
With others as a mirror, you can learn much.
With history as a mirror, you can know prosperity and decline.
—Li Shimin (an Emperor in Tang Dynasty of China, 598–649)

Chasing of relevance and balance between science and art, technology and humanities, is the instinct of human creativity. Exploring the potential of young students is an important task of modern universities.
—Tsung-Dao Lee (Chinese-American physicist, Nobel physics award winner, 1926–)

Machines are widely used in almost every aspect of human society, such as industry, defense and daily life. A middle school student can easily speak out a long list of machine names. College students in mechanical engineering around the world are in millions. People working on mechanical related jobs, including production, maintenance, research and education etc. are estimated in the scale of tens of millions. The number of people who have the opportunity to operate a machine is even larger. The automotive vehicles running around the world are estimated more than 1 billion. The industries relating with mechanical engineering contribute 9% of the nation's total GDP in China.

This book intends to describe the historical development and evolution of mechanical engineering. The purpose is to provide a comprehensive reference book for engineers, teachers and students in mechanical engineering who have the interest to learn the history of their profession.

Mechanical Engineering (ME) is a branch of applied science. It studies the theoretical and practical problems arisen in the development, design, manufacturing, installation, operation and maintenance of all kinds of machines with natural science and technological knowledge. ME is highly practical, of which technical experience formed in real production is a integrated part.

C. Zhang and J. Yang, *A History of Mechanical Engineering*,
https://doi.org/10.1007/978-981-15-0833-2_1

1.1 Historical Stages of Mechanical Development

In human history, development of machines can be divided into three eras: ancient era, modern era and contemporary era.

1.1.1 Ancient Era

The ancient era in this book refers to the period between the early Bronze Age to the Renaissance happened in Europe during the 14th–16th centuries, covering more than 5000 years.

Based on the material from which human made tools, the ancient human history can be divided into the Stone Age, the Bronze Age and the Iron Age. The Stone Age lasted millions of years. In 5000 BC, natural copper was discovered and began to be used. In 4000 BC, People in West Asia started smelting bronze, a copper and tin alloy, and making tools and weapons from it, marking the entrance into the Bronze Age. In 1400 BC, the technology of iron smelting appeared in Anatolian peninsula. In the Bronze Age, the bronze casting industry of the world was concentrated in Egypt and the West Asia, China, Southern Europe (mainly, the ancient Greece and the ancient Rome). These regions became centers of ancient human civilization, also centers of machine development of ancient times.

In history, the turning point from use of tools to use of simple machines was roughly coincident with the starting of Bronze Age. This is one consideration to choose the beginning of the Bronze Age as the starting point of "ancient era" in this book.

Thousands of years ago, human beings were already able to build pretty complicated machines, such as mortars and mills for grain hulling and grinding, shadoof and windlass for water lifting, vehicles, ships and various weapons. Human, animal, water and wind were the main sources of power by which these machines were driven.

There were a lot of clever ideas and brilliant creations embedded in the design of ancient machines, which are still inspiring and enlightening nowadays. However, the development and evolution of ancient machines were obviously very slow. From a purely technical point of view, one of the main reasons for the slowness was the lack of advanced power.

After the Capitalist mode of production appeared in the 14th century, societal evolution, economical activities, and the development pace of machines were significantly accelerated. The European Renaissance occurred in the 14th–16th centuries, as a great ideological movement, became the prelude to a series of great social changes, including the Bourgeois Revolutions and the Industrial Revolution.

In the academic community, there is not a consensus on the dividing line between the ancient and modern eras. In this book, however, the European Renaissance is taken as the separating point between these two eras.

1.1.2 Modern Era

The modern era in this book refers to the period from the European Renaissance to the end of WWII, covering several centuries.

After the Renaissance, science and art were greatly liberated. In the 17th century, the First Scientific Revolution emerged, in which the most representative achievement was the establishment of the classical mechanics. Following that, two ideological liberation movements, the Reformation and the Enlightenment, occurred. The bourgeois revolutions happened later in Netherlands, Britain and France further paved the way to the capitalism.

In this context, two industrial revolutions happened in Europe during the 18th–19th centuries. Power was the core of the two Industrial Revolutions. The First Industrial Revolution brought the world into the age of steam. The new power greatly promoted the use and invention of machines. Railways and steamships began to connect the world as a whole. The Second Industrial Revolution brought the world into the age of electricity. Automobile and aircraft fundamentally changed human society. Inventions went into an unprecedentedly booming period. Machine building was born as an industry and rapidly flourished. Machines were the main pillar of the two Industrial Revolutions. Mechanical engineering, which used to be in the form of personal skills of artisans, was gradually developed into a theory-based, systematic and independent modern discipline.

In view of the historical development, the modern era in this book is divided into three periods: (1) the period from the Renaissance to the eve of the 1st Industrial Revolution, (2) the period between the 1st and 2nd Industrial Revolutions, and (3) the period between the 2nd Industrial Revolution and the end of WWII.

1.1.3 Contemporary Era

Most historians take the turn of the 19th and 20th centuries as the dividing line between the modern and the contemporary eras. This book follows this convention, taking the new physics revolution, which happened at the turn of centuries, as the starting point of the contemporary era in view of the extremely important role of the new physics revolution in the technological revolution after. However, this treat would lead to an overlap of 45 years between the modern and the contemporary eras. Given the development of science and technological is always continuous, clear dividing lines in fact rarely exist. The new physics revolution laid a scientific foundation for the 3rd Technological Revolution, which was mainly triggered by the invention and wide application of computers after WWII. In the center of the 3rd Technological Revolution is information, instead of power which is the core of the 1st and the 2nd Technological Revolutions. After WWII, the universal increase of living standard raised an ever-high demand for high-performance machines, leading to intensive competition in the world market. At the same time, human activities to explore the unknown world were expanded to a much larger scale. These two aspects of demand drove the further development of mechanical technology and machinery industry with an unprecedented speed. The invention of computers along with progresses in relevant fields has provided powerful technical supports to the mechanical engineering. Thus, the contemporary mechanical engineering goes, in both breadth and depth, far beyond the modern counterpart does.

Revolutions in science and technology generally go hand in hand, but sometimes are twisted. During the upper half of the 20th century, a new technological revolution appeared in the horizon inspired by the new physics revolution when the second Industrial Revolution was still in progress. Several iconic achievements of the 2nd Industrial Revolution in either technology or industry production, including the invention of airplane, the development of the automobile industry, and the emergence of mass production mode, were all triggered by internal combustion engines. In view of this fact, the book does not strictly follow the chronological order in presenting the technological progress in the 20th century.

Mechanical engineering evolved into a discipline and further developed with accumulated inventions, technical improvement, and the establishment and growth of the machine building industry. Given that this book is intended for a history of mechanical engineering as a discipline, not for the machine building industry, we trace back to ancient time for inventions and technological improvement of machines for the purpose of completeness. As for the machine building industry, no detail is covered unless it is necessary.

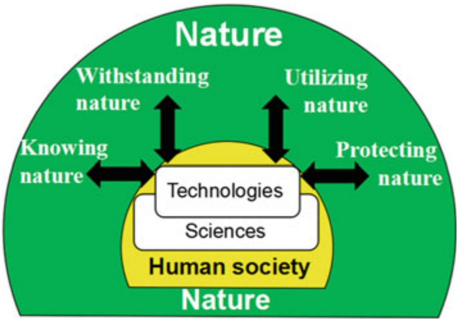
1.2 Key Relations in History of Mechanical Engineering

The history of a technology can be presented in two ways, internal history and external history (Liu et al. 2006). The so-called "internal history" presents the history from the solely viewpoint of the technology itself, while the "external history" takes into account the relationship between the technology and the economic and societal development. This book uses the latter.

To understand the history of mechanical engineering, attention should be paid to the following five important factors:

(1) relation between the nature, society and science and technology,
(2) the driving force behind the development of science and technology,
(3) the influence of society on the development of economy, science and technology,
(4) the relation between mechanical engineering and the natural science,
(5) the relation between mechanical engineering and relevant technological fields.

Fig. 1.1 Nature and human society



1.2.1 Nature, Society, Science and Technology

Two lines in parallel exist in human's history. To survive, humans take advantage of the nature, and at the same time, avoid possible harm from the nature.

To take the benefit and avoid the harm of the nature, humans need to know the nature. Science was born in this process. Science in turn greatly enhanced human's ability to understand the nature. To utilize the nature and avoid harm, humans need to rely on technology, which actually appeared before science. After the birth of science, science and technology became interacted. On the one hand, science has provided guidance and support to development of technology; on the other hand, since has gained development in the process of using technology to explore the nature.

After long history of getting along with the nature, humans came to realize that measures should be taken to protect the nature for human's long-term benefit. To protect the nature heavily relies on science and technology (Fig. 1.1).

1.2.2 Driving Forces Behind Science and Technology

Behind the development of science and technology are three important driving forces: the economic development, the national defense, and the scientific exploration of the unknown world.

To survive, ancient humans made tools, simple weaving machines, mortars and mills. Humans also built houses, ships and vehicles. To protect the tribe's benefit and compete for more resources for survival, weapons appeared. Although the standard of living was very low at ancient times, people already began to observe and explore the unknown world, for example, to observe the changes of seasons for planting in time.

The Industrial Revolution started from the textile industry in England. Steam engines were first invented for the purpose of providing power to the drainage pump in coal mines, but led to the establishment of railway transportation. The invention of internal combustion engines made automobile and aircraft a reality.

The impetus behind the development of machines is the economic development and the desire for higher standard of living.

After WWII, the development of the machine building industry was mainly driven by the formation of the global market and the unprecedentedly intensive market competition. The driving force behind the competition is the needs for higher quality and more comprehensive machines.

Humans have started observation of the universe since ancient times. Exploration activities have never been stopped. After WWII, the world has been retained in peace in general. More activities in scientific exploration, such as exploration of the deep sea and outer space, have been conducted. All these activities needed the support of science and technology. Consequently, a variety of high-end machines, such as the spacecraft and special robots, have been invented for these activities.

Although some science and technological development, those in ancient time in particular, are driven by the direct need for better life, the thirst for new knowledge is also an important driver for scientific development.

Scientific development, undoubtedly, benefits human society; however, the benefit may not come immediately. For example, some research in number theory and in astronomy, which may not be used in many years, is obviously valuable to the mankind in long term.

Micro-electro-mechanical system (MEMS) appeared in the 1960s was motivated by the etching process of integrated circuits. Initially people did not think of applications; instead applications were envisioned after the invention. For this reason, it is a scientific exploration. Science links with economy, but not as closely as technology does. Science has its own system and follows its own law of development. It is not the case that a direct economical driving force always exists behind science development.

The economic development, national defense and scientific exploration activities put forward requirements to science and technology, which in turn provide guidance and support to the activities in the three areas. This relationship is schematically illustrated in Fig. 1.2.

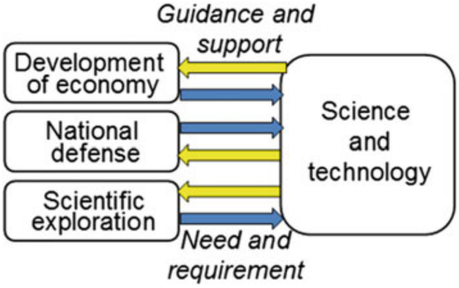


Fig. 1.2 Driving forces behind science and technology

1.2.3 Influence of Society

What is behind the economic development, national defense, and scientific exploration and technological development?

The answer is the society, more precisely, the development and evolution of the whole society.

The Industrial Revolution happened in England led to the establishment of the machine building industry. Was it possible for the Revolution to come earlier? The answer is "No". The English Revolution outbroke in 1640. As a result, a stable bourgeois regime was established in 1688 after the feudal system was abolished. Combination of the capital, labor and domestic market led to the rapid development of capitalist economy, which laid the foundation for the first Industrial Revolution.

Was it possible that the English Revolution happened earlier? The answer is "No" again. In the dull of the Middle Ages, how could a revolution outbreak suddenly? The premise of revolution is initiation of capitalist mode of production, gradual growth of bourgeoisie, spiritual liberation of the whole society, and public opinion preparation for the revolution.

Why could economy and science flourish after WWII? The core reason was the overall developments of society in the New Era, the long time peace of the world in general, improvement of living standards, ever intensive competition and the cold war, to name a few.

In general, the development of the society is a driving force to science and technology. In specific periods of time or specific regions, however, society may slow down or even stagnate the development of science and technology. The Middle Ages in Europe and the Ming and Qing Dynasties (14th–19th centuries) in China are examples of these periods.

In turn, science and technology may also inspire changes in society. Karl Marx believed that science is "a historically motive, revolutionary force"; it promoted productive forces, and sooner or later would cause changes in production relations and the social system.

Therefore, the history of mechanical engineering is not only compiling the biographies of outstanding inventors and a bunch of invention patents. Behind the grand picture of mechanical engineering history, there is a bigger picture of social development history.

1.2.4 Mechanical Engineering and Natural Science

Mechanical engineering is a discipline of applied science; it is based on the natural sciences, including mathematics, physics (mechanics, thermodynamics, Electromagnetics), and science of systems. Mechanics in particular is the most important theoretical basis.

Classical mechanics founded by I. Newton opened up a new era of science, laying the foundation not only for further development of mechanics, but also for the development of mechanical engineering, civil engineering and some other applied sciences. Today, all the theories of kinematic and dynamic analysis of various machines are derived from the Newtonian mechanics.

In the early days, the two cornerstone subjects in mechanical engineering, mechanism and machine science (MMS) and machine design, were part of applied mechanics. They were not becoming independent subjects until the 19th century.

Every new breakthrough in mechanics theory, such as the rigid body dynamics by L. Euler, the analytical mechanics by J.-L. Lagrange, elasticity by A.-L. Cauchy, and the multibody dynamics and finite element method after WWII, injected new power into the development of mechanical engineering.

In turn, the development of mechanical engineering put forward theoretical problems which need to be solved by the natural science, leading sometimes to the birth of new science. For example, the theory of multibody dynamics was created in response to the needs to study the dynamics of vehicles, spacecraft, robots, and even human bodies. Also, the need for increasingly complex calculation in dynamics promoted the development of new numerical algorithms.

1.2.5 Mechanical Engineering and Related Technological Fields

Development of related fields has significant influence on mechanical engineering. Progress in electromagnetics theory and the invention of motors in the 19th century influenced greatly mechanical engineering. Invention of computers and progress in control theory, after WWII, not only promoted the development of mechanical engineering, but also fundamentally changed the whole picture of machine design and manufacturing.

The 3rd Technological Revolution happened after WWII was characterized by information technology, involving new energy technology, space technology, biotechnology, new materials technology and marine technology. Mechanical engineering is closely related to all these areas and interacts with each other. This relation is illustrated in Fig. 1.3 and discussed in detail in Chaps. 9 and 10.

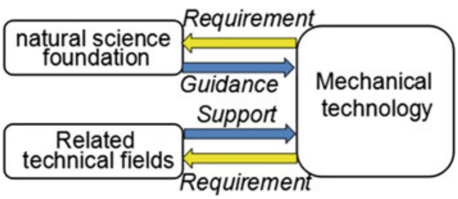


Fig. 1.3 Influence of science foundation and related technical fields

In describing the evolution of mechanical engineering, this book strives to clarify these important relations stated above. Effort is made to illustrate the background of society, economy and the whole science and technology behind the development of mechanical engineering.

1.3 Technological Revolution and Industrial Revolution

In the open literature, the definitions of technological revolutions and industry revolution are not in consensus.

Most of the literature supports that three Technological Revolutions and two Industrial Revolutions have completed in the last 200 years with the third Industrial Revolution ongoing. In some other literature, only the electrical power Technological Revolution is discussed without mentioning the second Industrial Revolution (Rifkin 2011; Jiang 2010). In some other works the 1st Industrial Revolution is termed as English Industrial Revolution, and the rise of the tertiary industry in recent years is called the “new Industrial Revolution”.

This book does not intend to comment on these differences in detail. Instead, focus is placed on the three concepts, namely scientific revolution, technological revolution and industrial revolution, and their relationship.

Scientific revolution means a great leap in understanding of the world by human beings, generally is in the form of a theoretic breakthrough. So far four scientific revolutions have happened as shown in Table 1.1.

Technological revolution is a major change in the means of human being’s transformation of the world. It is generally based on Scientific Revolutions, and leads to Industrial Revolutions.

Industrial revolution refers to the leap in the field of industry, such as radical changes in production mode or industrial structure. Industrial revolutions often directly lead to changes in economy and society.

Nicolaus Copernicus established the heliocentric theory, marking the start of the 1st Scientific Revolution. To the time when Newton founded the theory of classical mechanics, the first Scientific Revolution reached its climax. J. Hargreaves’

Table 1.1 Scientific revolutions in history

	Starting year	Main contents
The first	1543	Astronomy, classical mechanics, mathematics, human anatomy
The second	1755	Cosmology, geology, cytology, biological evolution, thermodynamics, electromagnetics, chemistry
The third	1895	Atomic structure, relativity, quantum mechanics, nuclear physics
The fourth	1946	Biological genetics, system sciences, nonlinear science

invention of the spinning Jenny represented the beginning of the 1st Technological Revolution, which was fully developed to the time when J. Watt invented steam engines. Steam power led to the widespread use of machines. As a result, manual workshops were largely replaced by mechanized factories, indicating that human entered the industrial society from the agricultural society. As such, this was generally regarded as the 1st Industrial Revolution.

Discovery of the electromagnetic induction phenomena by Michael Faraday was one of the most representative signs of the 2nd Scientific Revolution. The 2nd Technological Revolution was symbolized by the invention of electric motors, which brought the world into a new era of electricity. Correspondingly the electric power industry, steel industry, chemical industry and automobile industry rose. The fundamental change in industrial structure was the main sign of the 2nd Industrial Revolution.

Obviously, the 1st Technological Revolution is closely related to the 1st Industrial Revolution. So is the 2nd Technological Revolution to the 2nd Industrial Revolution. Following this convention, this book uses only the terms of the 1st Industrial Revolution and the 2nd Industrial Revolution.

The new physics revolution happened at the end of the 19th century is treated as the 3rd Scientific Revolution. The systems science established after WWII, however, marked the 4th Scientific Revolution. Mainly due to the war time need in WWII, the 3rd Technological Revolution came after the 4th Scientific Revolution. This Technological Revolution has created fundamental changes to the industry, and organization of business. Following the 3rd Technological Revolution, the 3rd Industrial Revolution, however, is still underway (Rifkin 2011).

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Chapter 2
Ancient Machines

Why had China been more successful than Europe in gaining scientific knowledge and applying it for human benefit for 14 centuries? And, given this lead, why did modern science originate only in Europe?
—Joseph Needham (British scientist, historian and sinologist, 1900–1995)

2.1 Introduction

The "ancient times" in this book, refers to a period of about 6000 years from the beginning of the Bronze Age until the European Renaissance in the 14th century. This section describes: (1) the three stages in using tools by ancient humans, and (2) the three main regions in ancient machine development.

2.1.1 Three Stages and Three Regions

Humans differ from animals by the ability of making and using tools. According to the materials of tools, ancient humans experienced three stages, the Stone Age, Bronze Age and Iron Age (Goddard 2010; Singer et al. 1954).

Humans used stone for millions of years. In the Old Stone Age (Paleolithic), all humans lived as hunter-gathers. Wooden and stone tools began to be used in this stage. Those tools, although being simple and primitive, were the ancestors of the "simple machines". Mesopotamia, Egypt and China first entered the New Stone Age (Neolithic). Thereafter people lived by farming and animal husbandry. Agricultural civilization began, and extremely simple farming tools, drawing tools, textile tools and canoes appeared. Virgin copper was already used in this stage.

Natural metals are limited in quantity and metal smelting occurred. Copper smelting was an important milestone in human development. Copper vessels of

C. Zhang and J. Yang, *A History of Mechanical Engineering*,
https://doi.org/10.1007/978-981-15-0833-2_2

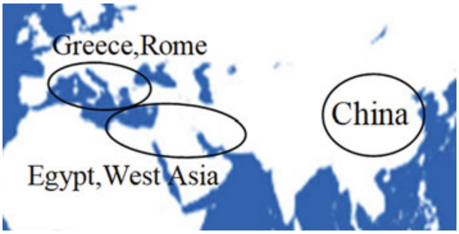

Fig. 2.1 Three main areas of development of ancient machinery

3800 BC were found in southern Iran, being regarded as the earliest items made through metal smelting.

In 3000 BC, southern Iran and Mesopotamia entered the Bronze Age first, followed by Egypt, Europe and China (Tylecote 1976; Ke et al. 1984). The bronze casting industry was also developed around these regions, which became centers of ancient civilization, and centers of ancient machine inventions (Fig. 2.1).

Around 2500 BC, Egyptian already obtained iron from meteorites, and used very small amount of ironware. Around 2000 BC, ironware also appeared in southern India. The Iron Age in the true sense, however, did not come until around 1400 BC, when the Hittite Empire in Asia Minor peninsula mastered the technology of smelting iron, and began large scale production of iron (Hua et al. 1985). Thus, copper was replaced on many occasions by iron. The technology of iron smelting was kept secret by the Hittite Empire, and was spread to the Middle East and Europe only after its demise (Stavrianos 1999).

2.1.2 The Dawning of Civilization: West Asia and Egypt

Human civilization appeared in West Asia and Egypt far earlier than in China and Europe. Thus, these two areas had also simple machines appeared the earliest. In 9000 BC, Jews in Palestine established Jericho, starting city civilization the first time in history (Gates 2003, 18). The earliest wheels maybe appeared at this time.

Many creations were first appeared in these areas, such as vehicles, ships, ploughshares, the shadoof, use of animal and wind power, lost wax casting, forging, primitive lathes and so on. However, further development at early stage was very slow. After the AD, no record was left on advances in tools and machine development in Egypt.

It was not until the 7th–15th century that a new peak came up in West Asia—Islamic civilization reached its golden age. Banu Musa brothers, Persian scholars, and Al-Jazari, a Kurdish scholar, published their books on mechanical devices and automatic machines in the 9th and 13th centuries respectively. The *Book of Knowledge of Ingenious Mechanical Devices* by Al-Jazari, in particular, was well known in the world, which described hundreds of machines and mechanisms. He

Fig. 2.2 Al-Jazari

stated repeatedly that all the devices described in this book were created by himself (Hassan and Hill 1986).

Al-Jazari was an engineering genius of the Islamic world in the Medieval Ages. He had rich inventions in a wide range, including mechanisms, components, automata and many fabrication techniques. He even created the first programmable humanoid robot (Al-Jazari 1973). According to Encyclopædia Britannica, the Italian Renaissance inventor Leonardo da Vinci might be influenced by the classic automata of Al-Jazari (Fig. 2.2).

2.1.3 Brilliance and Straggle of Ancient China

Although started later than Egypt by more than a thousand years, China kept in the top position in the invention of machines for a long time before the European Renaissance. These inventions covered a wide range, including not only various machines, but also many manufacturing technologies (Needham 1986; Liu 1962; Lu et al. 2009b; Lu 2012). In China, plough first appeared early in 3500 BC. Several other tools, including shadoof, windlasses, and blowers etc., were already used in the Shang Dynasty and West-Zhou Dynasty (1600–800 BC). In the late Spring-Autumn Period (about 500 BC), China entered the Iron Age.

After the AD, China rose in terms of creation and invention of machines simultaneously with the decline of Egypt.

Fig. 2.3 Zhang Heng

In the East-Han Dynasty (25–220) and the Three-Kingdoms Period (220–265), the most representative inventions made in China include the armillary sphere, the south-pointing chariot and the mileage drum wagon. Two outstanding inventors in this period are Zhang Heng and Ma Jun (Figs. 2.3 and 2.4).

In Song and Yuan Dynasties (960–1368), China reached the peak in technology of the Ancient time. The two most influential inventions in this period were gun-

Fig. 2.4 Ma Jun

Fig. 2.5 Su Song

powder and movable type printing. The movable type printing technology in particular, invented by Bi Sheng, was one of the greatest inventions in ancient China and had great impact on the development of printing technology around the world. The most outstanding mechanical invention of this period in China was the astronomical clock tower by Su Song (Fig. 2.5).

In 1405, Zheng He, an officer of the Ming Dynasty, led a large fleet of 240 ships and 27,400 crews and visited more than 30 countries over West Pacific Ocean and Indian Ocean. By 1433, Zheng and his fleet made a total of 7 voyages. Zheng's fleet set three world records of that time in sailing time, fleet size and sailing range, reaching the peak of maritime transportation in the ancient world. This achievement was an indicator of the manufacturing level at that time in China (Xin 2009, 98–102).

In 1637 (in Ming Dynasty), Song Yingxing published the book *Heavenly Creations* (Song 2009), which was the world's first comprehensive book on the production of agriculture and handicraft in the infancy of capitalism. It covered wide scope, including mining and smelting, casting and metal forging, operation of tools and machines, structure and application of ships, vehicles and weapons. This work was translated into many languages later. Due to its extremely important position in the world history of technology, it is referred to as "the encyclopedia of technology in China's 17th century" by European scholars (Fig. 2.6).

Zheng's fleet and Song's book could be regarded as two marks of the final glory of ancient Chinese technology.

Fig. 2.6 Song Yingxing and his *Heavenly Creations*

Liu Xianzhou (1890–1975), the first scholar on ancient history of machinery in China, pointed out (Liu 1962; Zhang et al. 2004): "*Generally, China's invention before the 14th century was not only superior in terms of quantity, but also far earlier in time. However, after the 14th century China fell gradually behind the Western. The basic reason for this was related to the social system*".

In a long period, rulers in China did not pay attention to development of industry and handicraft technology. Technical inventions were often regarded as "diabolic tricks and wicked craft". In the Ming Dynasty, the imperial examination became more rigid and dogmatic. As a result, intellectuals only focused on passing the exam and squeezing in government, with no interest in anything related to technology and practical knowledge.

Zheng and his fleet reached only the east coast of Africa, without getting a glimpse of Europe. Everywhere he saw was less developed in comparison with China. The information he collected from overseas only increased the hubris of Chinese rulers and the people.

In the mid and late Ming Dynasty, China adopted the "closed door policy". Qing Dynasty went even further to strictly limit trade with foreign countries. The rulers knew little about the change of society and development of science and technology taking place in the Western. The closed door policy not only prevented the trade and culture exchange between China and other countries, but also obstructed the path for China to learn the development of science and technology from the outside world. More importantly, it hindered the growth of the capitalist sprout in China.

At the same time, however, Europe was experiencing fundamental social and economic changes. After the Renaissance, ideology was being emancipated, scientific spirit was being disseminated, and productive forces were developing. Europe was well prepared to rise up.