MECHANICAL ENGINEERING

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Summary

The principle features and basic stages of mechanical engineering development are outlined. The indissoluble connection between mechanical engineering and the general history of the development of science, technology, and industrial manufacture, including an epoch of “scientific revolution” in the sixteenth and seventeenth century, is described, as well as that of the “Industrial Revolution” in the eighteenth and nineteenth centuries, and the scientific and technological progress of the twentieth century.

Close attention is paid to fundamental discoveries and to the significant contribution of pioneering industrial engineers and of outstanding scientists.

Modern trends in the further development of mechanical engineering are reflected. The importance of the role of mechanical engineering in the solution of global problems of life support on the earth in the twenty-first century is emphasized.

1. Introduction

In order to stay alive, primitive humanity had to find means of protection from natural calamities, enervating heat, and harsh frosts. In the course of their evolutionary struggle for survival, people learned to fabricate primitive instruments from the locally available materials: stone, wood, clay, and later metal. Ingenious solutions were found for lighting fires, and developing simple but efficient means of fishing, hunting, reprocessing and preserving of foodstuffs. The simplest instruments of production were created to construct houses and fabricate domestic utensils, as well as primitive types of weapons for protection against attack from wild animals attacks and for hunting (bows, arrows, and the like).

The first elements of the simplest appliances, machines, and mechanisms were: the inclined plane, the wedge, lever, and potter's wheel, later to be supplemented by the pulley, and the wheel. For a long time, primitive methods of transport used domesticated animals, harnessed in due course to various vehicles. The development of mechanisms for reprocessing materials and cultivating the soil, using not only human labor (often of slaves) but also domestic animals was a mainstay of technological development.

The struggle for survival, striving to improve instruments of production and methods of fishing and hunting, as well as the thirst for environmental knowledge (both on land and sea), stimulated the development of various means of transportation. At first rafts, canoes, and boats, then sailing vessels using wind power, were the basis for navigation, facilitating a great expansion of attitudes towards and understanding of the local geographical area.

The energy of falling water was used together with wind power. The first hydraulic machines were developed, the improvement of which still continues today in connection with the creation of modern hydro-electric power stations. The wind engines being perfected at that time were among the most ecologically friendly devices ever created by humans.

The search for improved transportation led to the exploration of steam power and the development of the steam engine. It was this and the discovery of electricity that sparked off the real science and technology revolutions, leading to the fabrication of steam ships, locomotives, railways, and automobiles, and a plethora of other inventions. In the twentieth century the development of the internal combustion engine and the car demonstrated the steady development of the fundamentals of machine science from the nineteenth century. Aspiring to ever-faster travel, people learned to fly. Today, one modern airliner can carry half a thousand people. In the most recent few decades, the atomic and aerospace industry have given an absolutely new revolutionary impetus to modern machine science development, and at the same time created new standards of safety and reliability for machines.

Computerization of all types of human activity has changed traditional approaches to methods and means of machine development. New technical means applied in medical diagnostics and in public health services have made it possible to protect humanity from epidemic diseases (cholera, plague, typhus, and the like). The world of micro-mechanics and robotics, success in bioengineering and biomedicine has opened the way to the development of novel approaches in human life support on the planet.

The particular role of engineering technology development in all spheres of human activity deserves to be emphasized: in improving standards of living, world outlook, communication between people, accelerated development of national economies, defense potential, expansion of opportunities to create a world without frontiers, global co-operation in outer space exploration and atomic energy, the design of supersonic airliners and high-speed transportation systems, up-to-date personal computers, modern communication networks and information transmission (television, radio soundings, satellite relaying systems, e-mail, facsimile and Internet communications), and finally, in solving the most acute problems of the twenty-first century: the problems of life support on earth and the natural environment.

2. Mechanical Engineering Stages

2.1. Origins of Mechanical Engineering

The term “mechanical engineering” came from the name of a technical engineering college established in England in 1837. Like machine science, mechanical engineering has deep historical roots. In ancient times, long before effective theories were developed, certain problems had been solved in practice, for example, how to construct edifices, fortresses, bridges, channels, and mills, as well as how to develop simple machines to maximize the effect of human labor.

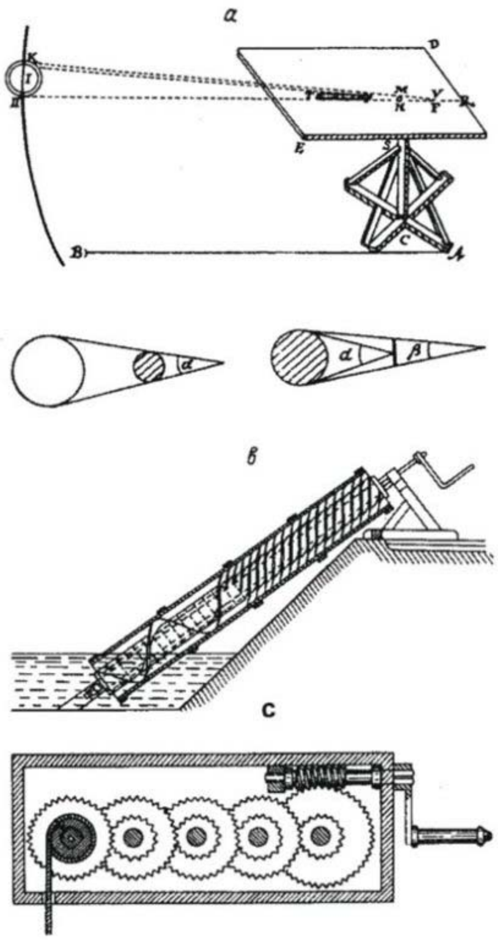

Figure 1. Mechanisms of Archimedes: a) a device for measurement of the visible diameter of the sun; b) “Archimedes’ screw”; c) a reduction gear
Source: Dorfman (1974); see also Archimedes (1962).

Different variants of inclined planes, wedges, levers, and units were devised, modifying those which already had been used on the basis of experience (Figure 1).

The great geographical discoveries of the fifteenth and sixteenth centuries stimulated the growth of cities, development of trade, and manufacture of commodities. Cottage industries and small workshops gave way to factories and plants. Manual labor was supplemented with the use of more and more sophisticated machines, the development of which demanded knowledge of the laws of mechanics and their application. The theoretical knowledge of the fifteenth and sixteenth centuries did not meet these needs, and medieval traditions persisted, for example, consideration of the fall of bodies and dynamic theory without appropriate verification of logical calculations derived from experiment. In this connection the activities of Leonardo da Vinci (1451–1519), the greatest scientist of the Italian Renaissance, and of his followers deserve particular consideration.

Leonardo da Vinci paid much attention in his memoirs to the solving problems of applied mechanics, and emphasized that experiment was of prime importance to him. As for his theoretical reasonings in the field of mechanics, they played only a subsidiary part. He was the first to have studied thoroughly the flight of birds and to approach the development of a flying vehicle that was heavier than air (Figure 2). Leonardo designed a number of schematics of machines and new mechanisms. He anticipated the idea of decomposition (partition) of the machine into separate mechanisms. His work with machines brought him to the study of friction, and he came to understand the impossibility of eternal motion almost three hundred years prior to strict evidence for that fact.

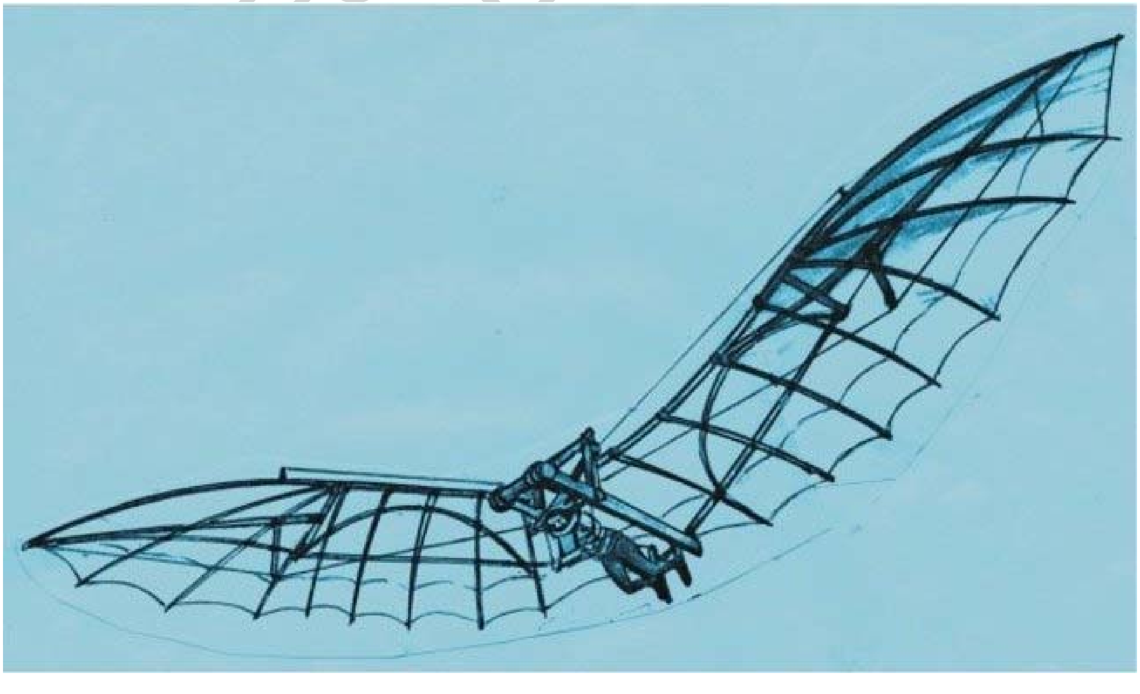

Figure 2. Flying vehicle developed by Leonardo da Vinci
Source: *Technical Encyclopedia* (1929–36).

Technical progress had long been constrained by lack of information. The achievements of the antique period in developing mechanics were published in Latin and Italian translations only in the sixteenth century. In 1501 Giorgio Valla published some mechanisms designed by Herone in his work, and in 1550 a number of machines by Herone were described by Girolamo Cardano (1501–1576). In 1575 and 1588 Federico Commandino published *Pneumatics* by Herone and *Mechanisms of Pappa of Alexandria* (Figure3). In 1543 the Latin translation of mechanical treatises by Archimedes was published in Venice.

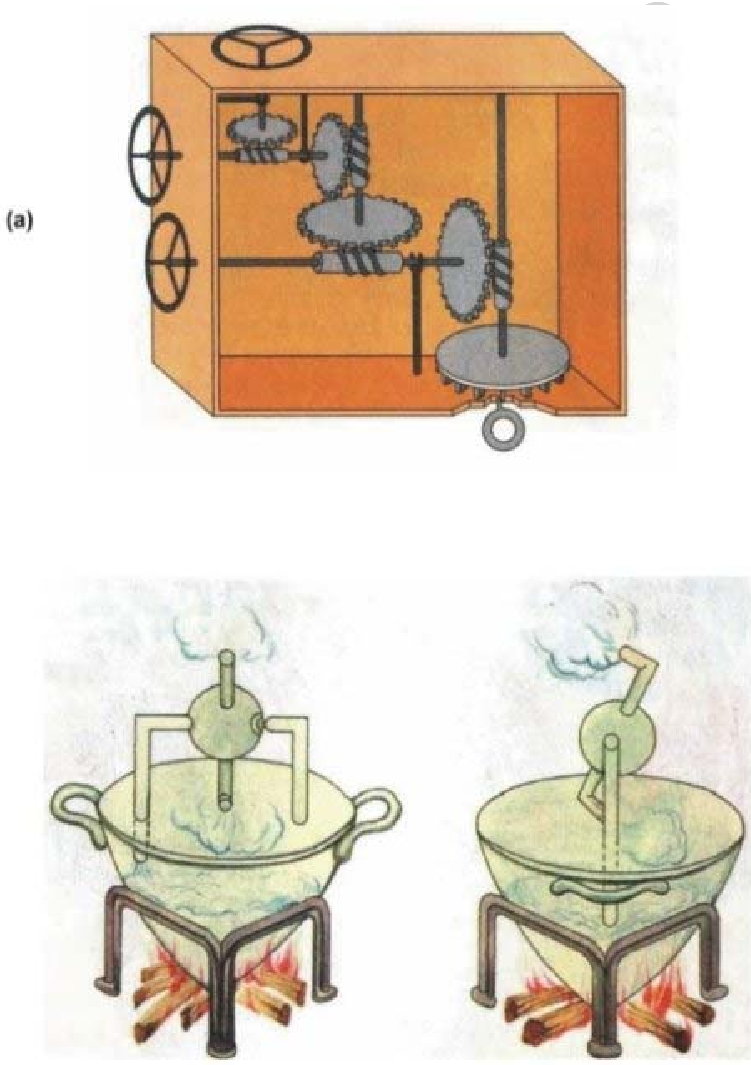

Figure 3. Mechanisms of Heron of Alexandria: a) distance measuring device; b) steam turbine
Source: *Technical Encyclopedia* (1929–36).

Around this time, independent works appeared containing results of the experience of mechanical engineers. A description of contemporary machine equipment was given in the works of Agostino Ramelli (1530–1590), Heinrich Steiner (1560–1613), and Caspar Schott. Ramelli, who belonged to the school of Leonardo da Vinci, depicted many interesting structures, water-pumping machines, and cranes in his work *Various and Skillful Machines*. Casparus Shott described complex installations of his time, in particular the machinery of a brewery, as well as hydraulic and pneumatic mechanisms and automatically driven installations.

Significant contribution into acquaintance of engineers with mathematics and mechanics was made by the Italian scientists Nicolo Tartaglia, G. Cardano, Vendetti, Commandino, and others. Tartaglia (1500–1557) published the Italian translation of Euclid in 1543, which was its first translation into a living European language, and an event of great importance in the development of applied mechanics. He prepared the Italian translation of works by Archimedes in 1551.

Girolamo Cardano was one of the most talented scientists of the Italian Renaissance. A mathematician, physicist, engineer, and astrologer, he studied a number of issues of applied mechanics and developed a significant quantity of mechanisms. In particular he considered gearing mechanisms and pointed out how to select gear design for obtaining a mechanism with the required number of shaft revolutions.

A wide circle of interests and universality are typical features of the scientists of the Renaissance. An engineer was also an architect and sculptor; a mathematician was also a physicist and astronomer. There were no narrow specialists, but there were inquisitive enthusiasts, and multi-experienced engineers who laid the fundamentals of mechanical engineering as a comprehensive, scientific, and applied concept that covers not only the theoretical activity of scientists in understanding processes connected with the transfer and transformation of motion and forces, but also the application of such data to the various areas of human work.

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Biographical Sketch

Konstantin V. Frolov was born in 1932 in Kirov, Russia. He graduated from the Briansk Institute of Transport and Machine Building in 1956 and received a Ph.D. in Technical Sciences (1962) and Doctorate of Technical Sciences (1970) from the Mechanical Engineering Research Institute in Moscow. He worked as an engineer in the Leningrad Metallurgic Plant, and was then a researcher, head of laboratory, Head of the Theory of Machines and Mechanisms Department at the Moscow State Technical University, and Director of theMechanical Engineering Research Institute of the Russian Academy of Sciences. He became a professor in 1971. He is a member of the Russian Academy of Sciences, and served as a Vice President of the Russian Academy of Sciences and the Academician-Secretary on Problems of Engineering, Mechanics, and Control Processes from 1985 to 1992.

Professor Frolov is the author of over 800 research papers, twenty monographs and textbooks, and editor of the 40-volume *Encyclopedia of Machinery* (Moscow, 1997). He is a distinguished member of many international academies and associations and is a founder and director of the International Institute of Safety. He has treceived many Russian and foreign awards, including Hero of Socialist Labour, Lenin and State Prizes.