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Contributions of Archimedes on mechanics and design of mechanisms

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ABSTRACT

Relevant contributions are ascribed to Archimedes as related to early developments in mechanics with application to mechanism design with a modern vision. Archimedes developed theoretical advances that were motivated by and applied to practical problems with an enthusiastic behaviour and with a modern spirit that can be summarized in his motto 'Give me a place to stand and I will move the earth'. In this paper his contribution to mechanics is discussed as related to his results in designing and successfully operating mechanisms.

1. Introduction

Since Renaissance Archimedes' mechanics has been reconsidered together with a new attention to Greek–Roman machine designs with the aim to develop an early approach for modern theory of mechanisms, as outlined in [1].

The works of Archimedes, mainly in the aspects of mechanism design, has been rediscovered and studied during Renaissance, as for example in the works [2–5]. They were used as fundamental backgrounds for the first developments of early TMM (Theory of Mechanisms and Machines) by Guidobaldo Del Monte [6] and Galileo Galilei [7,8]. Even at the beginning of the modern TMM in the 19th century Archimedes' contribution was recognized in identifying basic conceptual elements, like for example in the works [9,10]. The modernity of Archimedes in MMS (Mechanism and Machine Science) can today still be advised in his approach of classification for the variety of mechanism designs as function of a unique principle in the operation mechanics, as indicated in [11], following the earlier Aristotelian work 'Mechanical Problems'.

The major contributions of Archimedes that can be understood in the field of modern MMS, can be recognized in:

- identification and analysis of basic elements of machines and mechanisms, as pointed out in [8]
- analysis of machinery operation as function of a unique concept that he identified in the functionality of levers
- application of theory to successful practical designs that since his time gave dignity of discipline to machine design
- enthusiasm and optimism in mechanism design in developing technology for enhancing society and quality of life.

These aspects make his machine designs of relevant significance in the History of Engineering. In this paper attention is addressed to cranes with pulley systems, war machines, odometers, and other machine designs for which Archimedes' influence can be recognized.

From a viewpoint of the History of Mechanical Engineering, his achievement in defining and using an early concept of pair of forces and its equilibrium rule for the design and operation of mechanisms in machines was never too much stressed.

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In addition, the figure of archimedes and his works have been investigated since Antiquity and still today they are of great interest in studies and investigations that are reported in publications, like for example in [12–22], and encyclopaedias, like for example in the British Britannica and Italian Treccani, and in proceedings of specific conferences, like for example in [23,24], just to cite few ones from all around the world.

In this paper, attention is addressed in discussing the aspects and interpretation of the legacy of Archimedes in the modern MMS not only for a historical assessment but also as an inspiration for future achievements. The discussion has been focused on the aspects of mechanism designs from an engineering viewpoint.

2. Archimedes and his works

Archimedes (in classical Greek: Ἀρχιμήδης) was born on 287 B.C. and died on 212 B.C., Fig. 1a), [12]. He was a Greek philosopher in the classical term as being a mathematician, physicist, astronomer, inventor, and engineer, who lived in Siracusa that was considered the core of Magna Grecia at that time, Fig. 1b).

Nevertheless little is known of his life. Very probably during his youth he spent a period of study in Alexandria, Egypt, where he had the chance to know Conon of Samos and Eratosthenes of Cyrene. This seems probable since in his written works he cited them as friends. Archimedes was killed by a Roman soldier, when a long siege of Siracusa during the Second Punic war (214–212 B.C.) was ended, although Marco Claudio Marcelo, the Roman commander, ordered to save him. Cicero told that he saw Archimedes' tomb where a sphere was drawn inside a cylinder, as an indication of the main achievement that Archimedes recognized to himself.

In general, Archimedes is reputed for his contributions in Mechanics and Hydrostatics. He is also considered a reference personality in developments of Mathematics because of his calculations and theorems for volumes of solids and the number pi (π). Since Antiquity, he is also considered a unique inventor of new machines with an activity by which he applied his mathematical results to practical problems. The most celebrated machines are the screw pump and war machines that Syracusans used against the Romans.

However, although the inventions of Archimedes were known over the time, his written works were forgotten already in the last part of Antiquity and they were completely ignored during the Middle Ages. A first attempt to collect all his works was made by Isidor of Milete (about in 530). During Renaissance those works were reconsidered, like in the Latin translation by Jacobus Cremonensis in 1458 from a collection made by Eutocius in the 6th century. Only in 1906 a palimpsest was discovered with seven works by Archimedes in a better version than the previously known one.

The works of Archimedes, that are today known even through an interpreted text, like for example in [20], are:

- On the Equilibrium of Planes
- Measurement of a Circle
- On the Sphere and Cylinder
- On Spirals
- On Conoids and Spheroids
- Quadrature of the Parabola
- On Floating Bodies
- Stomachion
- Cattle Problem
- The Sand Reckoner
- The Method of Mechanical Problems.

Fig. 1. a) Portrait of Archimedes; b) the peninsula of Ortygia as the core of the ancient Siracusa with the Maniace Castle at its end.