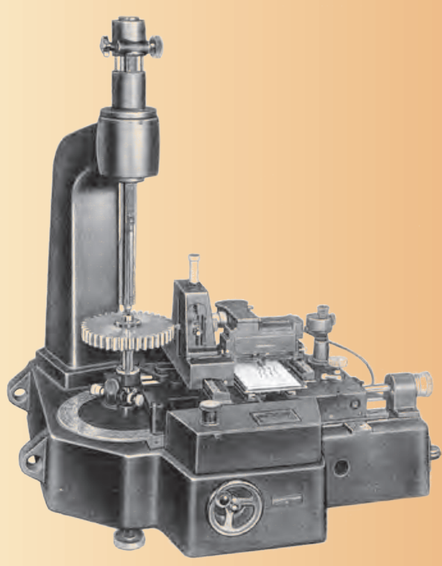
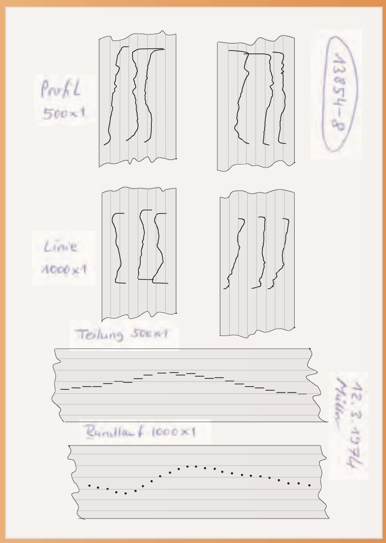
VOLUME 5

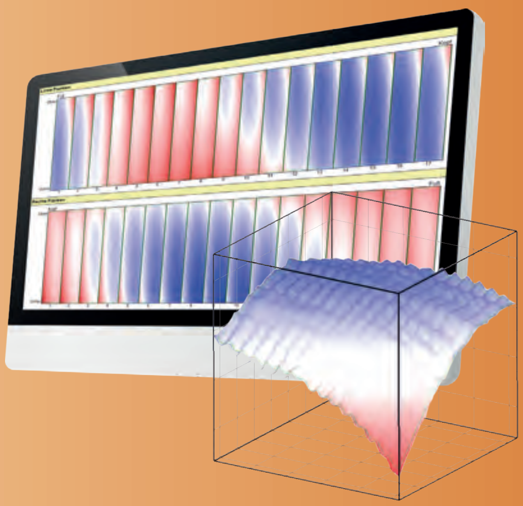
Jens Riesner

Rudolf Och

GEAR METROLOGY TROUGH THE AGES







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About this book

The gear is a commonly used symbol for industry, technology, complex issues and not least for the industrial revolution. However, it did not appear suddenly as a new idea of the 19th century; it was developed over millennia. Gears were very much disliked until the early 20th century, because of their difficult manufacture and the noise they generated. However, gears soon proved to be irreplaceable due to further developments and continuous improvements of the toothed systems.

One of the most important prerequisites for the resulting reliability is metrology. It usually works in the background and is most effective if the end-user does not notice its results, i.e. if it is so precise that errors can be excluded at production level already.

This book will look at the historical development of gears, the demands gear metrology had to face during the past hundred years and the changes that took place. A view of new, continuing methods, induced by progress in the information technology, will follow the comprehensive description of current, modern metrology.

The authors

Rudolf Och

Born in 1951 in Bamberg, Germany, studied mechanical engineering in Nuremberg and founded FRENCO GmbH in 1978. Since then the company has dealt with the subject matter of gear and spline metrology. During this time many ideas regarding patents and products, have been implemented. Rudolf Och has shaped the development of metrology and standards, has written about many topics within this specialised field and has lectured professional audiences on it.

Jens Riesner

Born in 1978 in Nuremberg, studied history and political science at the Friedrich-Alexander-University Erlangen-Nürnberg, Germany. After graduating in 2007 he founded Historica, a company that offers historical research and museum concepts for companies and local authorities. The company creates chronicles, city guides and scientific papers for a variety of customers from industry and culture. During the preparation of this book he was responsible for the research and the summary of historical facts.

Jens Riesner Rudolf Och

Gear metrology through the ages

History - Presence - Future

Co-authors: B.Eng. Philip Jukl, Prof. Dr. Günther Gravel
Layout/typesetting: Raphael Endres
Translation: Alexandra Timmis
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Contents

Foreword

The technical progress of gear and spline metrology has currently reached an odd standstill. This may be due to an over-regulation of standards and regulations, or due to the complexity of the subject matter or even due to the requirements to the mind and the software. There are many intellectual approaches for an extensive consideration, solids (as they are required for computer tomography), best-fit and enveloping concepts as well as new evaluation methods. There is, however, a distinct lack of will, or maybe it is due to the difficulty to convert such approaches. The aim of this book is to describe the historical developments, the current situation and a possible future of gear and spline metrology; it aims to stimulate the minds of the, admittedly, few specialists in this field.

Rudolf Och

Introduction

It may seem strange for a historian to venture into the world of technology, especially into a difficult subject like gear metrology. The gear itself is regarded as a complex geometric component, whose ideal shape requires a higher understanding. Adding to this issue a subject like metrology will certainly pose a problem to the humanities scholars. Surrounded by formulas and technical terms, he will first have to find a suitable access. But fortunately the historian will find access within history and now begins to understand the development step by step until he has got the full picture.

Of course, before metrology is described in detail, the history of the gear itself must be explained. From the ancient Egyptians via Greece and Rome, the journey through time takes us to the Middle Ages and the Renaissance. Metrology has its beginnings with the industrial revolution.

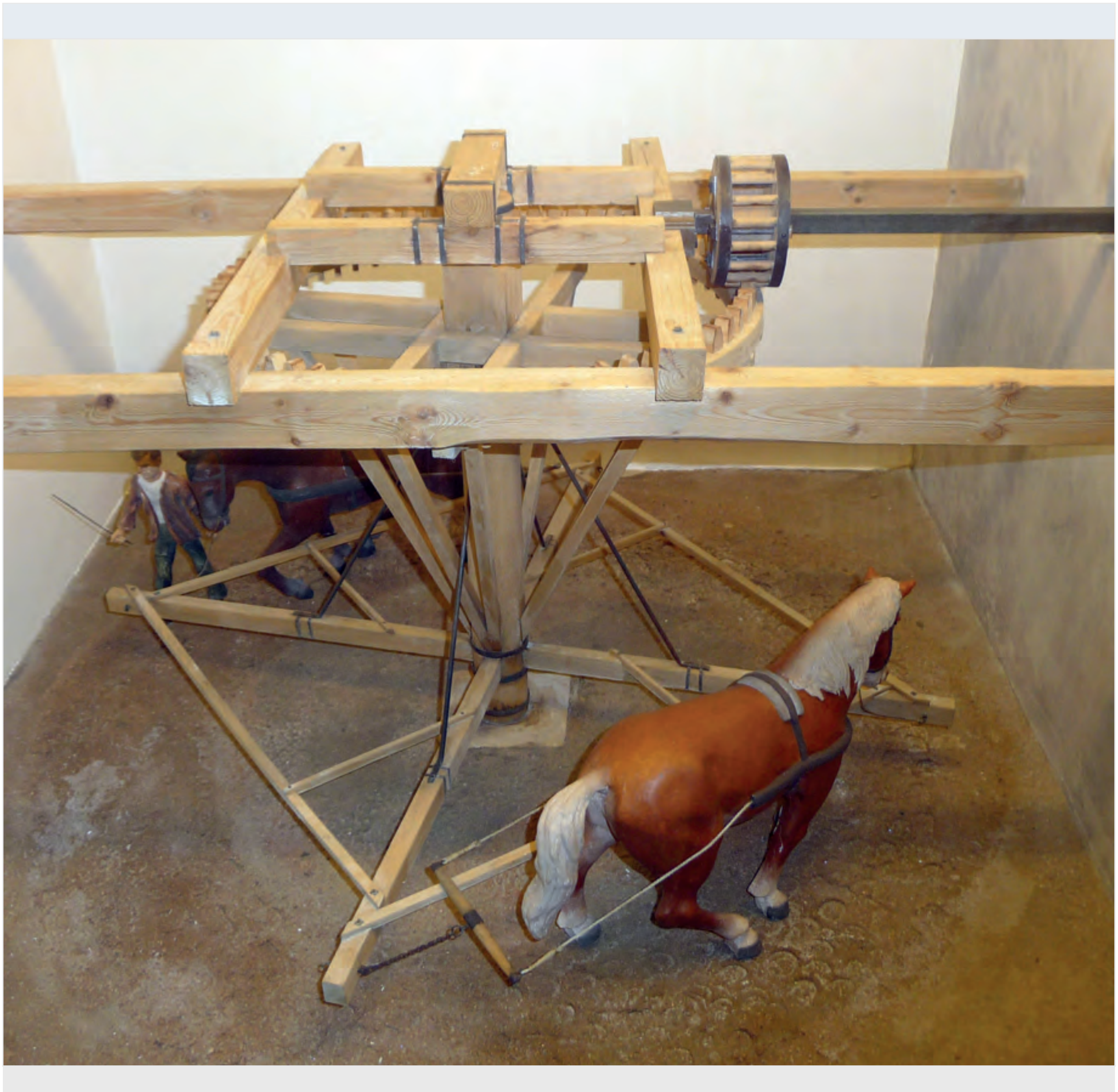
Although it has only existed for just over a century, there were various developments whose presence is determined by the start into the digital generation. New measuring instruments and evaluation procedures were created and enabled the manufacture of gears that are more and more perfect.

It is possible to identify and describe the individual steps, successes and the persistent problems without any profound technical knowledge by carefully analysing the individual development steps.

After many discussions, intensive research and evaluations, it ultimately shows that the historian might, in the end, be closer to technology than he initially thought. The secrets of metrology have, to some degree, revealed themselves. This book will hopefully help to convey an impression of the complexity of the gear itself and of gear and spline metrology.

Jens Riesner

1 History



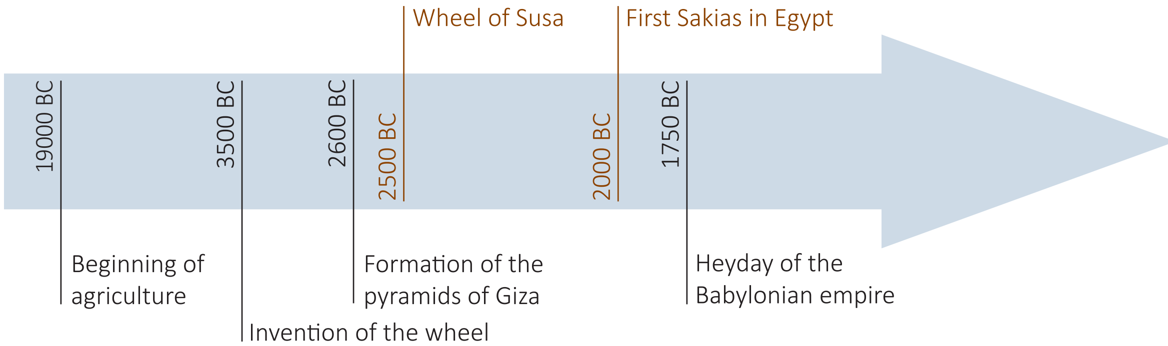
Researching the gear and spline metrology requires sound knowledge of the development history of the gear itself.

The first primitive gears appeared as early as 2500 BC in Ancient Egypt in well lifting mechanisms. Similar simple gears also existed at this time in the Asian region. Refining the technology started in ancient Greece around 400 BC: scientists such as Archimedes or Aristotle took care of the matter and started to analyse gears. When the Roman Empire started to expand in 200 BC, Greek knowledge found its way to Rome. However, further exploration of the technology was then largely abandoned. Only a few thinkers like Heron or Vitruv showed an interest in gearing. Nevertheless, gears in the antique had long ceased to be just a tool for wells. Even though they were still most commonly used in wells, scientists - since the ancient Greeks - experimented with far more delicate gears compared to those used in the primitive lifting machines.

With the invasion of the Visigoths 410 AD the Roman Empire collapsed and important achievements of technology disappeared with it. The knowledge of gearing dropped back to almost pre-antique times and gears appeared almost exclusively in mills.

Assessing the early development of technology, especially of course of gears, comes to its initial end with the decline of the Roman Empire. The development, which was quite straight up until this point, undergoes its first break. It took nearly a thousand years before the loss of this technology was regained.

Early history - the wheel marks the beginning (2500 BC- 500 BC)



1.1.1 The first “gear”

The origin of the gear is closely connected with the technical progress of the wheel. Further development and an improved construction led eventually to the first wheels which showed an optical similarity to gears.

They were from 2500 BC and where discovered near Susa, Persia (Fig.1). To protect the wooden wheels of carts, copper nails where hammered into the wheel tread. The purpose of these nails was to minimize the wear on the wheels.

Fig. 1: The wheel of Susa

The wheel has studs which makes it appear similar to a gear. The metals studs, however, only served to increase the grip of the wheels. The “engagement” effect of these studs is a typical characteristic of gears. The wheel of Susa is hence accepted as one of the first gears.

The wheel of Susa is certainly not the first gear in history, but its wedge-shaped projections were already evident. It therefore represents one of the first special types of a wheel, which could have easily developed into gears. An indication of this may also be the location of the city of Susa. It was in Persia, modern Iran, and hence located next to Egypt, where somewhat later the first primitive gear profiles emerged.[1]

1.1.2 Sakias of Egypt

The first practically used gears were developed, through simple practical considerations, in Southeast Asia. In fact, farming along the river Nile, which has always been Egypt's lifeline, required this development. To this day, many canals that irrigate the arable land, branch off the river. However, the Nile only has a very gentle gradient of just 90 meters over a distance of 1100 km, which meant the canals had to have a higher water level than the river itself. This height is necessary in order to create a downward slope into the fields. Egyptian farmers, in ancient times, therefore had to develop lifting devices (Fig 2).[2]

A draft animal set the horizontal wheel, on which rods where placed at regular intervals, in motion. These rods then meshed with a similar wheel, which was mounted vertically and drove the waterwheel via its axis. This is how the water was transported into the irrigation ditches higher up. For the first time ever, the Sakias were able to prove the change in direction of movement by the use of gears. It cannot be verified exactly at what point the Sakias appeared for the first time. The German engineer Max Eyth claimed that the first of these jack systems had already been shown on images of old

Fig. 2: Replication of a Sakia in Pollença (Mallorca)

While in the foreground buckets carry the water to the top, a lantern gear drive, which was typical for Sakias, ensures that the horizontal rotation of the large driven wheel is converted into a vertical rotary motion.

tombs of the Pharaohs. The pictures from this time do however show common drawing wells. The first real proof for Sakias can be found around the time of our common era. The first systems are probably considerably older, since much more complex gear wheel drives had been used in Greece around 300 BC.[3]

The gear profile of the Sakias' were simple and technically not at all advanced. But they met the requirements of the farmers. The teeth were rough round sticks which were driven into pre-prepared holes. Even without exact verification of the origin, the Egyptian Sakias are considered the archetype of the later gearing (Fig 3). The earliest record of a gear profile confirms that the advanced civilization of the Eastern Mediterranean countries were the creators of the gear. A water lifting machine, which retrieved water from a well using gearing, was situated in the king's palace of Byzantium around 600 BC.[4]

Since this system was also much more sophisticated than the Egyptian jack systems, the Sakias must be considerably older. It must be presumed that their time of origin was between 2000 and 1000 BC.[5]

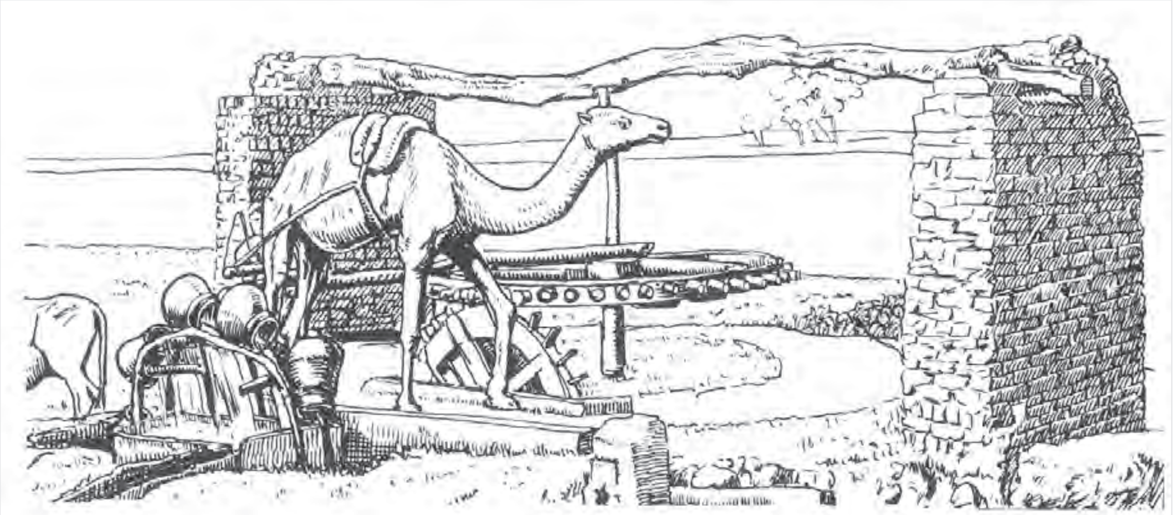


Fig. 3: Drawing of an ancient Egyptian Sakia

The principle of operation is clearly visible. The pack animal moves the larger gear. This then rotates the second, smaller gear, which is connected to a bucket wheel that carries the water to the top.