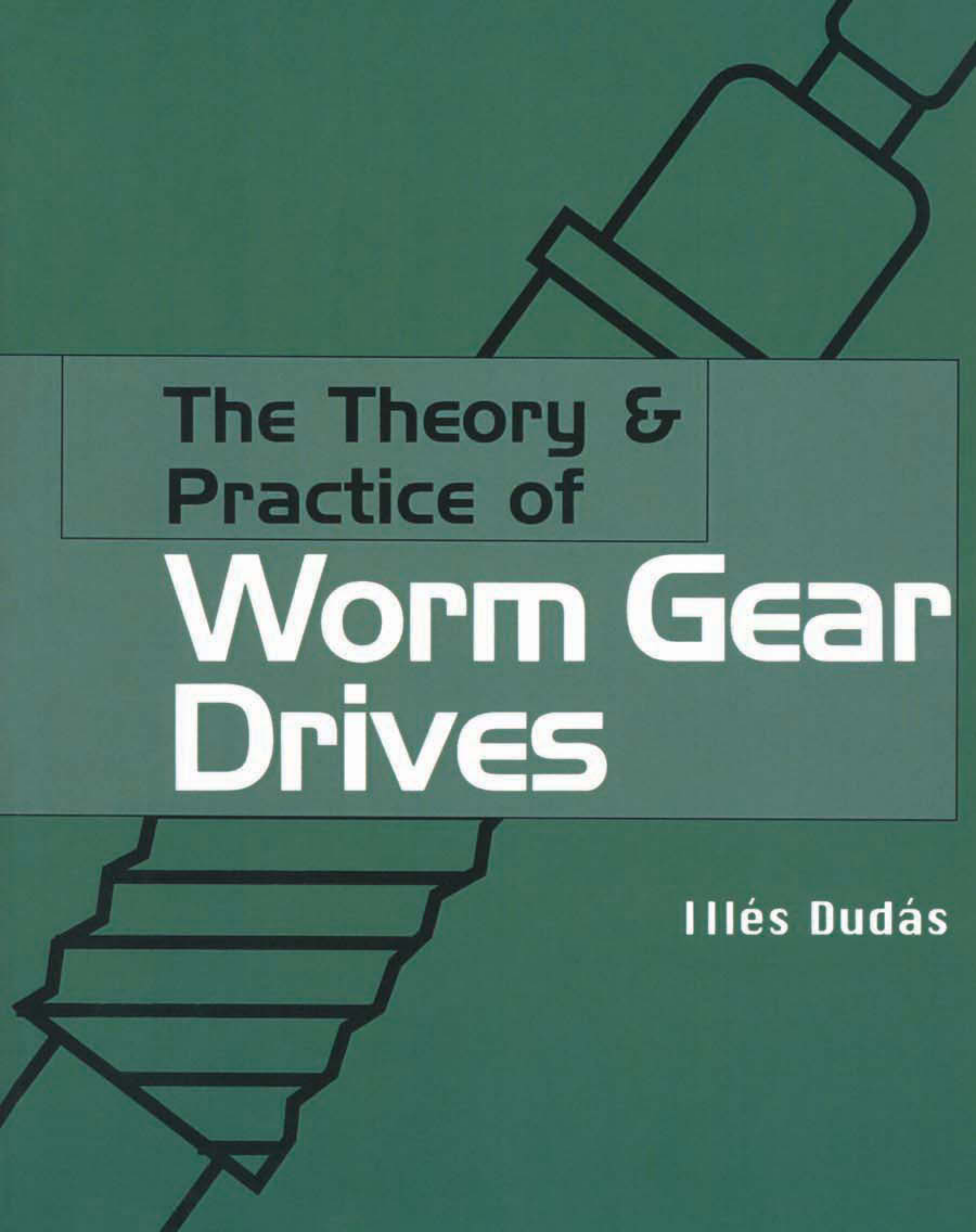
The Theory & Practice of Worm Gear Drives



Illés Dudás

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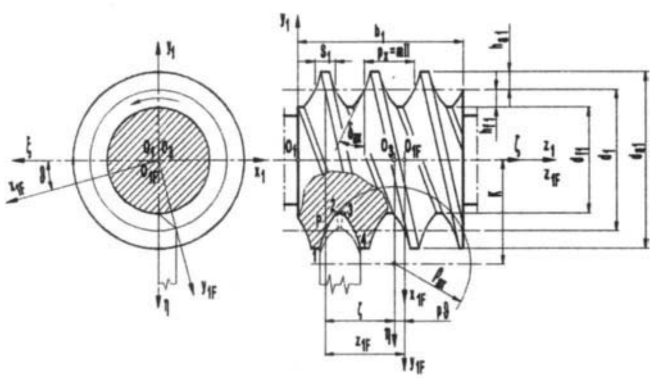

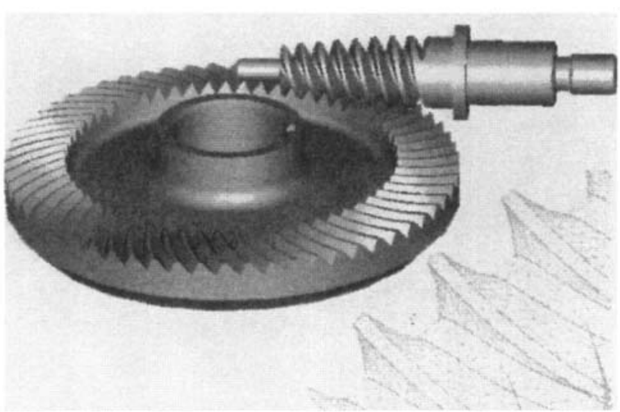

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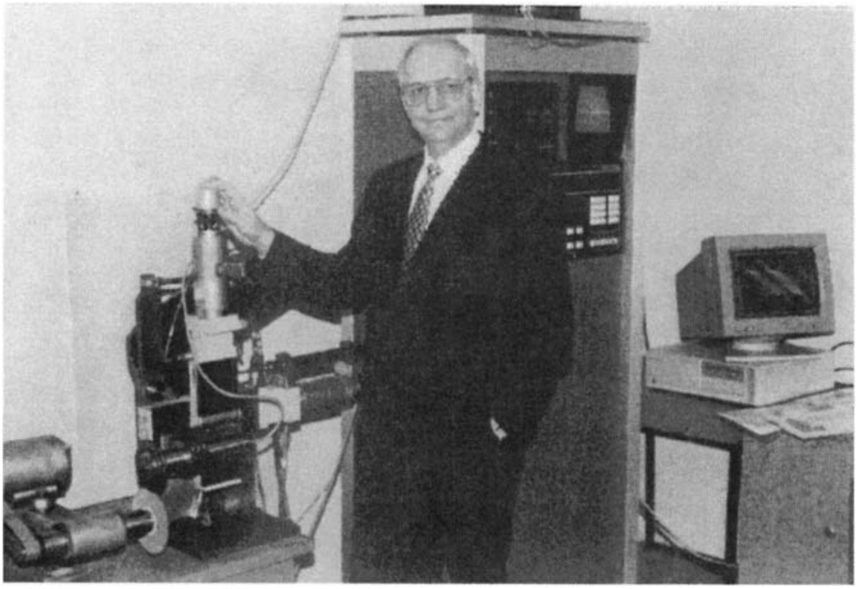
To my wife, three children and parents



The author with his early CNC grinding wheel dressing experimental equipment

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FOREWORD

The writing of this Foreword to this book presents me with a wonderful opportunity to recall my visits to Miskolc and my meetings with the distinguished scientists and the friends that I was lucky enough to make there.

My friends from Miskolc, Professor Zeno Terplan and Dr Jozsef Drobni, gave me the best present that I could have asked for – they translated in 1972 the Russian edition of my book *Theory of Gearing* into Hungarian.

I was delighted to find in my conversations with Drs Imre Levai, Zeno Terplan and Illés Dudás a mutual interest in topics such as non-circular gears, planetary trains and worm gear drives.

The greatest reward for a scientist is to have a following, and this I found in Hungary.

My joy in this could perhaps best be expressed by citing the famous verse 'The Arrow and the Song' by Henry Wadsworth Longfellow:

I shot an arrow into the air,
It fell to earth, I knew not where;

And the song, from beginning to end,
I found again in the heart of a friend

I hope that this short introduction explains why I am grateful for the opportunity to write a Foreword to this excellent book written by Professor Dudás.

The generation and manufacture of worm gear drives and the design of tools (hobs, grinding disks) for worm and worm gear generation is an important area of research. The application of CNC machines to the manufacture of worms and worm gears, their precision testing, and the computerized design of tools have broadened the horizons of research and have required from the researchers a good knowledge of the theory of gearing and specialized topics in differential geometry.

In this book Dr Illés Dudás makes a significant contribution to these topics of research; included are the author's summaries of the results of research obtained by himself and other researchers. In addition, Professor Dudás demonstrates the results of his great and wide experience in the design and manufacture of worm gear drives and in neighbouring subject areas.

The contents of the book cover the main topics of the design and manufacture of gear drives. I am familiar with the research performed by Professor Dudás whom I was able to meet at International Conferences (in San Diego and Dresden) and at our University, and by exchange of our publications.

There is little doubt that this book will be prove to be a most useful work for researchers and engineers in the area of gears.

Faydor L. Litvin
University of Illinois at Chicago
Chicago, USA
1999

PREFACE

Automation is playing an ever-increasing role in the development of both product and manufacturing technologies. Automation provides important means of improving quality and increasing productivity as well as making production more flexible, in line with changing needs. State of art computer control now has a role for machine tools and in manufacturing technology. Design of the product as well as of manufacturing equipment has been taken over by computer-aided, and sometimes by completely automated, systems. In the increase in efficiency of manufacturing processes and product quality, the most important element has been computer-aided engineering.

Helicoid surfaces are often used in mechanical structures like worm gear drives, power screws, screw pumps and screw compressors, machine tools, and generating gear teeth. Therefore many research and manufacturing organizations are becoming involved with their design, manufacture, quality control and application.

Theory and practice in this field are usually treated separately in textbooks. There are significant differences between different machining technologies, and checking methods for helicoidal surfaces are not always designed and manufactured precisely and optimally.

I have been particularly fortunate to have been able to work, during the course of my career, in many fields of engineering. During my years as a professional engineer I always felt attached to scientific investigation concerned with the correlation between construction and manufacturing technology. Following a short period in industrial practice I worked, for ten years, as a designer. My first assignments were the design of service equipment (for example the DKLM-450 type wire-rope bunch lifter), and later, wire pulling stages, wire–end sharpeners, etc. The need for an improved worm gear drive arose in the course of this work.

The machine factory at Diósgyőr (DIGÉP, Hungary) was using wire pulling stages and decided to modernize them, to reduce their noise level, weight and cost along with developing an increase in the efficiency and load-carrying capacity. The modernization was carried out successfully so that the kinematically complicated drive systems were simplified too.

The experience gained during tests showed that drive systems fulfilling exacting requirements can only be solved by using special worm gear drives. The technical development of worm gear drives at DIGÉP resulted in worm gear drives with different geometries such as convolute helicoids with limited bearing capacity, worm drives with rolling contact elements and helicoidal surfaces curved at their axial section. Comparing them, it became clear that the development of curved axial section type helicoidal surfaces was called for.

Research in the fields of manufacturing technology development, as well as toothing geometry of mated pairs and the overall checking and quality control of these drives, are summarized in some of my published works (Dudás, 1973, 1980, 1988b).

Worm gear drives designed and manufactured by application of this newly developed method have operated efficiently both in Hungary and abroad in a range of different products.

In my present position as Head of Department of Production Engineering at the University of Miskolc, it has been possible to continue my previous research work in this field, to fill gaps in the work and to search for a possible description of their generalized geometry, starting from the common characteristics of the different types of helicoidal surfaces.

This book basically aims to clear up geometrical problems arising during manufacture and provide theoretical equations necessary to solve them, thus filling a gap existing in publications in the field.

In the nine chapters of the book, both theory and practice are covered. The contents may be summarized as follows:

1. This introductory chapter provides the reader with a view of the aim of the book and provides a short review of the history of worm gear drives.
2. An analysis of the literature of the subject and a summary of conclusions to be drawn from it concerning the field covered by the book.

3. The theory needed for the proper geometrical manufacture of helicoidal surfaces of constant pitch is introduced here. Further, a mathematical model is developed, suitable for the handling of the production geometry of both cylindrical and conical helicoidal surfaces.
4. Introduces a general mathematical kinematic model for both cylindrical and conical worm gear drives, as well as the design and manufacture of the necessary tools.
5. Newly patented truing equipment for grinding wheels is described.
6. Checking methods for helicoidal surfaces are described.
7. Design methods and the procedures for manufacturing helicoidal surfaces using intelligent CIM systems are introduced.
8. The basic theory, operational characteristics and the possible applications for drives are summarized in this chapter.
9. Comprises a summary of results of research work.
10. A full bibliography of publications relevant to the subject of this book is included in References and Further Reading.
11. Index.

In writing this book, it is the author's hope that it will prove useful for those involved in both graduate and postgraduate work in research and development and also practising engineers in industry.

Illés DUDÁS

ACKNOWLEDGEMENTS

In the course of the research on which much of the content of this book is based, there were many people who assisted me or contributed directly or indirectly to my work. To them, I would like to give my heartfelt thanks.

While I cannot manage to mention all of those involved, I should like to express my grateful thanks to the following, who helped and encouraged my development in this area of research.

First, from my undergraduate days, when I first became interested in the correlation between research and manufacture, Dr József Molnár, who played an important role in bringing to my attention the lack of precision in the WFMT; in the various phases of my research, Drs Károly Bakondi, István Drahos and Imre Lévai, and also Drs Tibor Bercsey and József Hegyháti of the Technical University of Budapest for their active and helpful collaboration.

My thanks are also due for the help of Professor Dr Zéno Terplán, who was the Head of Department of Machine Elements at the University of Miskolc for several decades, and I am grateful for having been able to consult Professors Friedhelm Lierath (Otto-von-Guericke University of Magdeburg), Boris Alekszeyevich Perepelica (Technical University of Kharkov) and Hans Winter (Technical University of Munich).

I should like to express special thanks to Professor Dr Faydor L. Litvin (University of Illinois, Chicago), whose work helped me in my basic research and who allowed me to consult him personally, and I should like to acknowledge my debt to Dr F. Handschuh (NASA Glenn Research Center), whose critiques in various publications of The American Society of Mechanical Engineers increased the scope of my awareness.