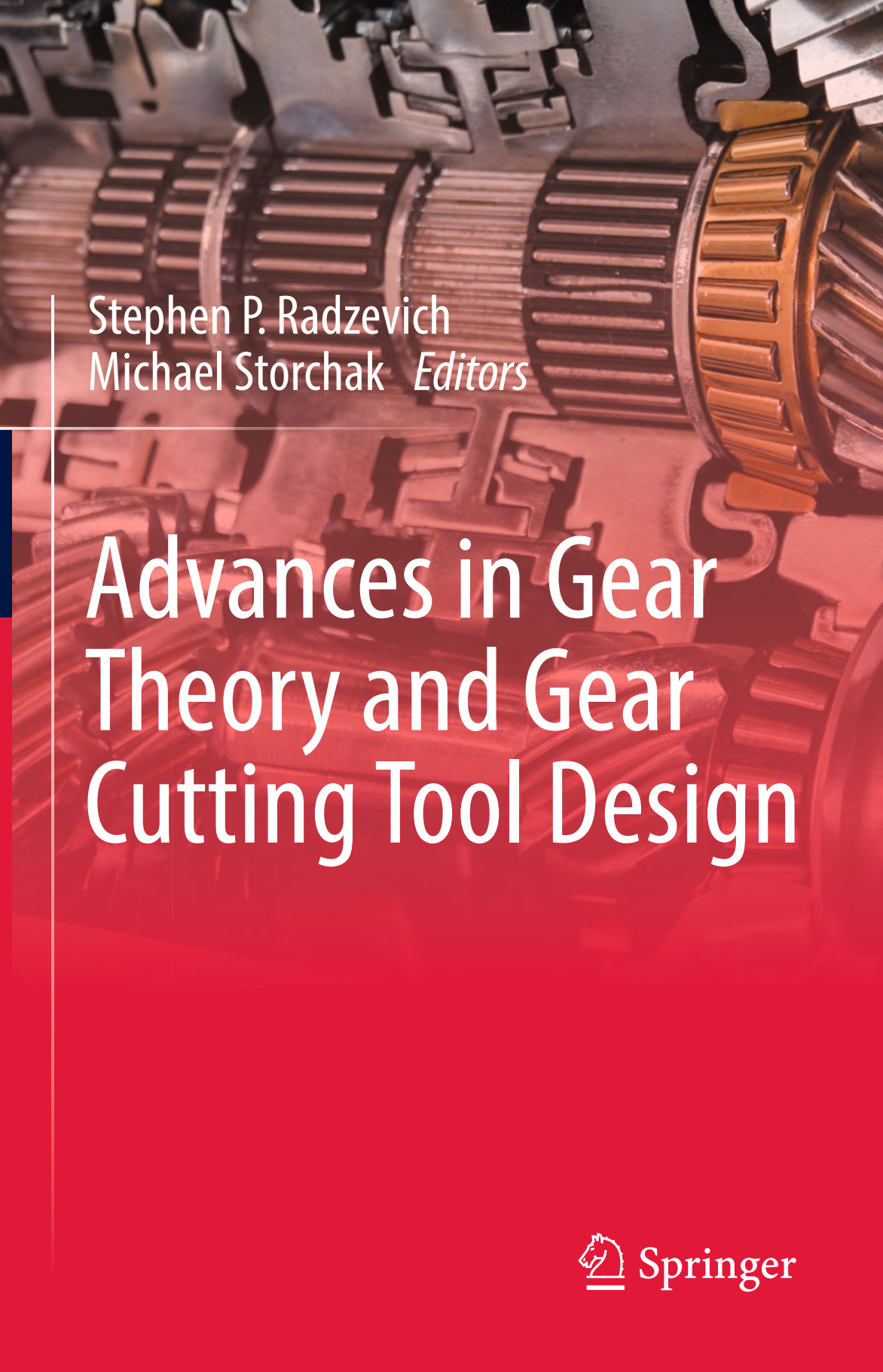

Stephen P. Radzevich
Michael Storchak *Editors*

Advances in Gear Theory and Gear Cutting Tool Design

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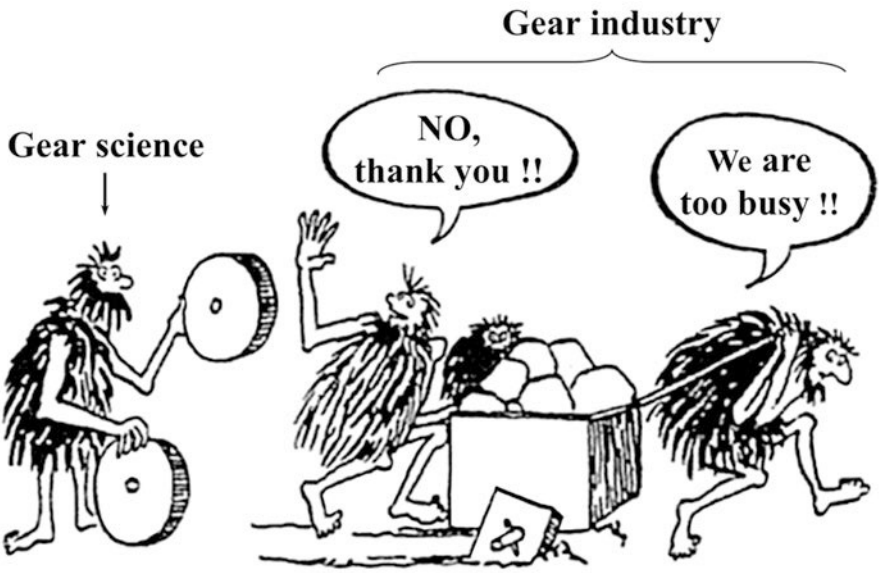
Introduction



Knowledge is power (*Scientia potestas est*)
Francis Bacon

Historical Background

Gears were invented by smart humans centuries ago. It took a long time for gear designs to evolve from wooden pin gears to present-day designs, featuring enormous power density and capacity of transmitting rotations of thousands of revolutions per minute and huge amount of power.

Current gear designs are based on the latest accomplishments in the theory of gearing. Sophisticated gear-cutting tools are extensively used in producing high-quality gears. Ultimately, these gear sets yield a very high degree of reliability.

Despite the extensive past research in this field, gear science and gear practice have evolved further in recent decades. The accumulated experience in the field of gearing, both from the theory side as well as from the experimental side, has been summarized in several fundamental monographs, novel experiments have been carried out in recent years, and important new research results of have been obtained. This volume is focused on the advances in gear theory and design of gear-cutting tools.

Uniqueness of This Publication

This book is an invaluable source of information on gear theory, gear design, gear production, and gear application. The world's leading experts in gear science have contributed their latest accomplishments in the field of gearing. The most important subjects in gear science have been covered in this book. Numerous gaps between the current needs of advanced gear designers and gear manufacturers have been bridged by gear science. This book is unique as the latest accomplishments in the scientific theory of gearing and in production and application of gears have been considered to the best possible extent.

Intended Audience

A team of world-renowned experts in the field of gearing, gear theory, and gear-cutting tool design has contributed to this book. This volume is dedicated to gear experts involved in gears and transmission systems of advanced design, that is, gear drives with highest possible power density (in other words, *power-to-mass ratio*) and low noise (or almost "*noiseless*") gear transmissions. Most gear engineers and gear researchers in the industry, as well as graduate students, will benefit from the book.

Organization of This Book

The book's 15 chapters have been organized into four sections in which advances in gear theory and gear-cutting tool design are discussed.

I. Accomplishments in the Theory of Gearing

This section comprises Chaps. 1, 2, 3, and 4. Recent accomplishments in the theory of gearing are briefly outlined here.

Chapter 1: Contributed by Prof. *Stephen P. Radzevich* (USA), this chapter deals with geometrically accurate gears and gear pairs of all possible kinds. Parallel-axes gearing (or just P_a-*gearing*, for simplicity), intersected-axes gearing (or just I_a-*gearing*, for simplicity), and crossed-axes gearing (or just C_a-*gearing*, for simplicity) are covered in this chapter.

The consideration is focused mainly on three fundamental laws of gearing. These laws of gearing are as follows:

1. *The law of contact*, commonly referred to as the *first fundamental law of gearing*
2. *The conjugate action law*, commonly referred to as the *second fundamental law of gearing*
3. *The law of equal base pitches*, commonly referred to as the *third fundamental law of gearing*

It is proven that in geometrically accurate gearing of all three kinds, namely, in P_a - , I_a - , C_a-*gearing*, all three fundamental laws of gearing are fulfilled. Only approximate gearing can be designed and manufactured when one or more fundamental laws of gearing violated.

Chapter 2: This chapter is written by the gear experts (*D. Babichev*, *S. Lebedev*, and *M. Storchak*) having an extensive experience in the approach proposed by Prof. *Dmitry T. Babichev*. Gears and worm gears are an important part of many machines and mechanisms. The reliability and durability of gears largely determine the quality and competitiveness of machines in general. The scientific basis for the design of gears and gear-cutting tools is the gearing theory. The main research object of this theory is complex surfaces formed by enveloping methods, and the main tool is software-implemented algorithms for modeling the shaping processes. The creation of reliable simulation algorithms is hindered by the imperfection of the applied methods and mathematical models of gearing theory. A precondition for improving such methods and models is fundamental theoretical research in the field of gearing theory, enabling the creation of computational models more adequate to the real processes of shaping and contact of moving bodies than the existing ones.

This chapter presents the results of further development of the gearing and surface-shaping theories fulfilled by Prof. D.T. Babichev during more than 50 years of his life and professional activities. His coauthors attempted to compile and prepare the results of the research, almost as originally outlined by Prof. Babichev.

Chapter 3: Contributed by Prof. *Stephen P. Radzevich* (USA), this chapter of the book pertains to the scientific theory of gearing, and to generating of envelope curves and surfaces in particular. All three kinds of gearing, namely parallel-axes gearing (or just P_a-*gearing*, for simplicity), intersected-axes gearing (or just I_a-*gearing*, for

simplicity), and crossed-axes gearing (or just C_a-*gearing*, for simplicity) are considered in this chapter.

It is a commonly adopted practice to generate tooth flanks of gears for P_a - , I_a - , C_a- *gearing* as envelopes to an appropriate family of curves and surfaces. Unfortunately, not every envelope curve and surface can be used in design of gears for geometrical accurate gear pairs. As rolling motion is a vital component of kinematics of enveloping process, an additional requirement must be fulfilled to get two envelope surfaces to be conjugate to one another. Pair of envelope surfaces of this sort are also referred to as reversibly enveloping curves and surfaces (or just as R_e-*curves* and surfaces).

It is proven that in geometrically accurate gearing of all three kinds, namely in P_a - , I_a - , C_a- *gearing*, tooth flanks feature R_e−*surface* geometry.

Chapter 4: This chapter is written by gear experts from China, Dr. *Yaping Zhao* and *Tianfeng Wang*. The new theory in regard to the meshing limit line is systematically established for the Archimedes worm pair. The equation of an Archimedes helicoid, the meshing function, and the meshing limit function for the worm pair are all obtained in different form and by means of different method from the past. In light of these more laconic results, it is strictly proved that the meshing limit line for an Archimedes worm drive always exists in general and cannot be removed by the adjustment and/or re-arrangement of the parameters. As far as the most limit points of the second kind are concerned, the curvilinear coordinate parameters are acquired analytically and no iteration is needed. The numerical outcome states clearly that the meshing limit line usually locates roughly at the middle of the worm thread length. This is the theoretical reason why the working length of an Archimedes worm generally cannot exceed half of its thread length. Generally speaking, the conjugate line of the meshing limit line lies in the middle of the tooth surface of the worm gear and divides the whole conjugate zone into two parts. Moreover, the conjugate line can commonly go through the full tooth height from the top to the root.

II. Gear Manufacturing Methods

Recent accomplishments in the field of gear manufacturing methods are discussed in this section of the book. This section of the book comprises Chaps. 5, 6, 7, 8, and 9.

Chapter 5: This chapter is contributed by an international team of researchers in the field of gearing (*S. Pasternak*, *Yu. Danylchenko*, *M. Storchak*, and *O. Ohrimenko*), who represent Germany and Ukraine. Gear cutting with disc-shaped milling cutters is characterized by a loose connection between the cutting tool and the gear tooth profile and provides possibilities to increase productivity and reduce manufacturing costs compared to gear cutting with shaft milling cutters. Various methods for gear cutting with disc-shaped milling cutters were developed and successfully implemented on the conventional machining centers. To be able to select an optimal machining strategy and suitable process parameters for each

specific manufacturing task, knowledge about the characteristics of the known methods for gear cutting with disc-shaped milling cutters is necessary.

This chapter is dedicated to theoretical studies of the known methods for gear cutting with disc-shaped milling cutters. Firstly, by analyzing these methods, it was found that they differ in strategies for material removal, tool movement, and tool engagement and, therefore, provide different productivity, flexibility, and machining quality. Then, mathematical models of the form-shaping kinematics (movements of the cutting tool relative to the workpiece) were developed for process simulation. Finally, trajectories, velocities, and accelerations of the machine tool components as well as material removal rates were calculated when gear cutting by using these mathematical models.

Chapter 6: In this chapter, contributed by Dr. *O.I., Skibinskyi,* and Dr. *A.O., Hnatiuk*, (both from Ukraine), principal peculiarities of the gear wheels geometry for the g-rotor pair are considered. The question concerning profiles-curves synthesis of gearing is solved. To ensure the absence of "degenerate areas" on the equidistant, the distance of its removal should be less than the minimum radius of the epicycloid curvature $\rho_{\min}$. An analytical description of the enveloping family equidistant to epicycloids in a single continuous form is given. This is achieved by reducing the function of the epicycloid angular coefficient to a smooth continuous form, which in turn allowed obtaining a rational analytical solution of the relationship equation between the parameters of the construction and the curves family.

Worm tools for highly efficient processing of the satellite profile and an analytical description of their initial shaping contours are presented. A new tool for highly efficient finishing of spur wheels with large numbers of teeth is presented.

Chapter 7: This chapter is written by *B.S. Vorontsov*, *V.A. Pasichnyk*, and *Yu.V. Lashyna*, all from Ukraine. Modern computer technologies provide conditions for the creation of highly efficient systems for gears shaping. This greatly speeds up the gear design process while ensuring quality. A mathematical description of the surface reduced to a universal form on the basis of unified control parameters is proposed. This provides an approximation of the point representation of surfaces by spline surfaces and creates the basis for the use of unified methodological, algorithmic, and software automation of the shaping process. This approach makes it possible to evaluate the shaping process directly during the interactive analysis of gear shaping, including a preliminary assessment of geometry and kinematics of the shaping process. The used unified parameters of the shaping system provide the possibility of integrating the shaping system into automated design, production, analysis, and control systems.

Chapter 8: This chapter is contributed by Dr. *I. Hrytsay* from Ukraine. Today, involute spur gears are the most widespread transmission component for various industrial applications. However, besides of the numerous benefits, involute teeth present several disadvantages. To overcome those, designers resort to changes that increase the complexity of equipment, cutting tools, which leads to the high price of gear boxes and transmission. On the other hand, gear and transmission, namely sinusoidal gear and transmission, have been known since the last 50 years of the twentieth century. This work also presents the results that confirm that sinusoidal

gear higher bending strength, lower contact stress, reduced contact friction and tension in the edging contact, improved performance indicators of transmission. The advantages are due to the following features of the sinusoidal gear's geometry: gear tooth root profile outlined by a smooth sine wave curve, greater teeth thickness on the pitch circle, and wide range of coast flank pressure angle. Moreover, a new efficient and technically simple cutting technology to manufacture gears has been invented. This technology makes it possible to reduce the number of expensive and complex gear-cutting tools and gear machine tools, which greatly simplifies gear machining and reduces the cost of gear manufacturing manyfold. The method is versatile and provides the opportunity to produce arbitrary types of internal and external gears and pinions: spur or helical, cylindrical or bevel, worm wheels, and gears with asymmetrical teeth.

Chapter 9: Contributed by Dr. *Michael Storchak* (of Germany), this chapter deals with finishing of involute gear teeth. The result of a technological system design is to determine its optimal parameters and structure, which provide the specified properties of the product. The chapter proposes principles for building a technological system based on a systems approach. The principles are implemented in the form of a logical design scheme. This model regulates the design process with information, optimization, and algorithmic systems, regardless of the processing type. Using the developed method, several technological systems have been designed for gear finishing. Particular attention is paid to technological systems for finishing with a rigid kinematic connection between the tool and the gear to be machined and to systems with free rolling. Examples of technological systems for combined machining, systems with multi-tool set-up, selective tracking, and systems for ensuring the tools shaping are considered and designed. The designed technological systems are tested under real conditions in gear finishing. Thus, the proposed methodology can be used to design technological systems, in particular, to create the systems for gear finishing.

III. Gear Transmissions

Principal features of gear transmissions of novel design are discussed in this section, which comprises Chaps. 10, 11, 12, 13, and 14.

Chapter 10: This chapter is contributed by Dr. *Vladimir B. Algin* from Belarus. The architectonics of the gear train information model (digital twin), developed on the basis of the lifetime mechanics of machines, is presented, and its main components – concepts, representations, models, and methods – are described. These provisions and methods were created within the framework of the scientific school founded by *Igor Tsitovich*, corresponding member of the Academy of Sciences of Belarus. Brief historic data are given. Currently, this direction is being developed at the Joint Institute of Mechanical Engineering of the National Academy of Sciences of Belarus. They have developed architectonics containing several new components: three method of gear trains synthesis, universal kinematic-quasi-static

calculations for gear transmissions of any configuration, simulation of dynamics based on concept of a regular mechanical systems, strength calculations in the lifetime form, space of operation conditions, reliability calculations according to multilevel "mechanics-dependability" scheme, and a special method for reliability calculation under the general load conditions of the components. Basic representations of the transmission (kinematic diagram, a set of dynamic schemes, life-strength curves, schemes of limiting states, etc.) appear in the development process and go through all stages of life cycle. These components are complemented at the operational stage by transmission diagnostics and evaluation of its lifetime expense as a complex item and serves as accumulators of new knowledge and data about the item and its operation conditions (environment). The methodological provisions developed for the transmissions are applicable to a wide range of engineering objects. They are also presented in the state standards of the USSR and the Republic of Belarus.

Chapter 11: Written by Dr. *Konstantin B. Salamandra* from Russia, this chapter of the book deals with split power transmission systems. Vehicle transmissions are built on the basis of two types of geartrains: with fixed axles of gear wheels (layshaft geartrains) and planetary geartrains. Layshaft transmissions simply allow increase of the number of speeds by adding the appropriate number of clutches and geartrains with the required gear ratio. But the power flow in layshaft transmissions transmits only by single path; therefore, loads acting on internal transmission's links are maximum. Planetary transmissions have a higher load capacity and, in addition, allow the division of power flow into several parallel paths. The creation of multi-speed planetary transmissions is complicated by a significant increase in the number of planetary gear sets and clutches. This chapter deals with multi power-flow transmissions containing combinations of layshaft and planetary geartrains. The main advantages of planetary-layshaft transmissions are the use of simple geartrains, reduced loads on the internal links, a wide ratio range, and the implementation of more speeds at fewer clutches.

Closed planetary-layshaft transmissions have only two possible structures with two power flows and four structures with three power flows. The chapter shows examples of new kinematic diagrams of multi-speed multi power flow planetary-layshaft transmissions. A method for calculating the gear ratios of the geartrains that make up the transmission, which satisfy the specified series of speed ratios, has been developed.

Chapter 12: A team of the researchers, *A. Kryvosheia*, *O. Ustynenko*, *O. Krasnoshtan*, and *P. Tkach*, under the supervision of Dr. *Mykola E. Terniuk* investigated multi-parameter gears and gear-type variators, which represent further development of traditional (one-parameter) gears and existing variable speed drive's designs. The purpose is to transfer torque in kinematic or power variable machines and transformer mechanisms. They differ in that they allow you to adjust not one controlled parameter – the angle of rotation of the drive wheel – but two or more parameters. Multi-parameter gear drives with one pair of engagement allow you to additionally change the relative position of the axes, and gear variators, to constantly adjust the gear ratio. These devices are of complex mechanisms. They can have a

continuous or continuous-discontinuous operation, reproduce the required gear ratio theoretically accurately or approximately. Due to using of gears, multi-parameter gear drives and gear variators allow power to be transmitted by normal components of forces; therefore, they have a high efficiency and low specific material consumption. The spheres of utilization of these devices are general mechanical engineering, automotive industry, tractor and combine building, drives of technological machines, and robotics.

A multidimensional classification of multiparameter gears and gear variators is proposed. The classification considers the speed, load, and functionality of the devices. It is shown that the structure of multiparameter gears includes mechanisms that allow changing the mutual arrangement of the axes while maintaining the meshing conditions. These mechanisms require a control system (unit). Gear variators also have mechanisms that allow adjusting the trajectories of the internal variator links, cause change in the gear change. It needs to be connected to the control system.

The teeth of multi-parameter gear drives and gear drives that are part of variators form higher kinematic pairs, the contact point of which to be optimized

The shaping of the tooth of multi-parameter gears can be carried out using traditional or additive technologies.

Chapter 13: Professor *Yu.Danylchenko*, Dr. *A.Kryvosheia*, Dr. *V.Melnyk*, and Dr. *P.Tkach* have contributed a chapter that substantiates the need as well as technical and economic feasibility of the creation of a new technical system for the synthesis of cylindrical gears and its supporting mathematical models and information technologies, taking into account the life cycle of gears. The structure of the technical system, the concept, and the principles of creation and operation are presented. The considered system will allow synthesizing gears with higher qualitative indicators and providing validation of all the stages of its life cycle.

Generalized unified mathematical and logical model of direct and inverse shaping of flat gear systems with an arbitrary profile and use of the theory of affine space mapping has been developed.

Features of approaches to the solution of mathematical models and creation of algorithms in this paper consist of the following:

- Refusal to describe the profiles of details and tools by equations in favor of point sets
- Refusal in most problems to derive equations to determine the wanted points of the profile in favor of certain conditions

It is shown that information about cross-cutting technologies of product life cycle stages can be used not only to increase an efficiency, productivity, and profitability of business processes, but also to classify kinematic schemes of formation, create new mechanisms or radically improve already known, using new processing methods. technological processes, expansion of the field of existence of the stages of a life cycle of products, generalizing math-models, information technologies, modern technical means.

This chapter, as a specific example, reveals the features of direct and reverse shaping of gears, taking into account the points of fracture, undercutting, displacement of the original forming contour, the required size and shape of the allowance, the sequence of technological shaping.

Chapter 14: Written by a team of gear scientist from Ukraine (Dr. *E. Posviatenko*, Dr. *B. Lyashenko*, Dr. *N. Posviatenko*, and Dr. *Ya. Mozghova*), this chapter considers the main stages of the gear system development in time, analyzes the current state of the gear wheel theory and technology used in mechanical engineering, gives information on the basic gear materials, and considers trends and sources of gear wheel hardening.

It shows that the most promising methods for increasing the service life of gear wheels in terms of bending and contact endurance, as well as in terms of wear, are the combined methods of surface engineering. These methods involve the combined action of protective coatings and modification of the surface layer.

One of the sources for increasing the load capacity of power transmissions is the need to regulate the hardened layer thickness depending on the tooth modulus and surface hardening technology. The load-bearing capacity of the teeth also depends on the gradient of properties in the transition zone and on the thickness ratio in multilayer coatings.

This chapter shows that when designing gears, it is necessary to achieve equal resistance of the engagement surface to contact wear and of the tooth root – to bending fatigue.

The chapter analyzes the advantages and disadvantages of individual technologies and evaluates promising solutions. It shows that one of the promising methods of surface hardening is ionic nitriding. To ensure the maximum load-bearing capacity of the gear wheel, the surface layer configuration should be optimized according to the principle of minimizing the stress-strain state. The source for increasing the load capacity of gears is also the use of coatings with discrete structure.

IV. In Memoriam of Professor Dmitry T. Babichev

Just one chapter comprises this section of the book. This chapter is in memoriam of Professor *Dmitry T. Babichev*.

Chapter 15: This chapter (in memoriam of Professor Dmitry T. Babichev) is contributed by Dr. *Victor Eu. Starzhinsky* of V.A. Belyi Metal-Polymer Research Institute at the National Academy of Science of Belarus.

Prof. Dmitry Tikhonovich Babichev was a famous scientist in the field of theory and practice of gearing. The memorable meetings of the author with him are described in this chapter.

The author met Prof. Dmitry T. Babichev at numerous scientific conferences and workshops in Izhevsk, Russia (1996, 1998, 2004, 2008, 2014, and 2017); Sevastopol, Ukraine (2009–2013); St.-Petersburg, Russia (2015); and Krakow, Poland (2019). Also, they worked together on the global publishing project (unfortunately,

unfinished) – multivolume edition "Gear Trains," which, on intention, incorporates the invaluable experience of famous scientific schools of well-headed masters, fully formed in Russia, Belarus, and Ukraine. Prof. Dmitry T. Babichev was a very obligatory and multiple personalities, he fundamentally worked under any new topic. His responsibility and scrupulousness were evident in a variety of cases. A long-term and multifaceted Ph.D. and Doctoral thesis preparation are among them.

Contributed by Prof. *Stephen P. Radzevich*, appendices are titled as follows:

Appendix A: Elements of Differential Geometry of Surfaces
Appendix B: Applied Coordinate Systems and Linear Transformations
Appendix C: Contact Geometry of a Gear and a Mating Pinion Tooth Flanks
Appendix D: Closest Distance of Approach between a Gear, and a Mating Pinion Tooth Flanks
Appendix E: On Inadequacy of the Terms "*Wildhaber-Novikov Gearing*" and "*W-N Gearing*"

It is likely this book is not free from omissions or mistakes nor is it as clear and ambiguous as it should be. If you have any constructive suggestions, please communicate them to the editors via e-mails: radzevich@usa.com and mstorchak02@googlemail.com.

Sterling Heights, MI, USA — Stephen P. Radzevich
Stuttgart, Germany — Michael Storchak

Contents

About the Editors

Stephen P. Radzevich (editor) is Professor of Mechanical Engineering and Professor of Manufacturing Engineering. He holds several degrees, an M.Sc. (1976), a Ph.D. (1982), and a Dr.(Eng)Sc. (1991) – all in mechanical engineering. Dr. Radzevich has extensive industrial experience in gear design and manufacture. He has developed numerous software packages dealing with *CAD* and *CAM* of precise gear finishing for a variety of industrial sponsors. His main research interest is *kinematic geometry of surface generation*, particularly with the focus on (a) precision gear design, (b) high power density gear trains, (c) torque share in multi-flow gear trains, (d) design of special purpose gear cutting/finishing tools, and (e) design and machining (finishing) of precision gears for low-noise/noiseless transmissions of cars, light trucks, etc. Dr. Radzevich has spent about 40 years developing software, hardware, and other processes for gear design optimization. Besides his work for industry, he trains engineering students at universities and gear engineers in companies. He has authored and coauthored over 30 monographs, handbooks, and textbooks. The monographs entitled *Generation of Surfaces* (2001), *Kinematic Geometry of Surface Machining* (*CRC* Press, 2008), *CAD/CAM of Sculptured Surfaces on Multi-Axis NC Machine: The DG/K-Based Approach* (M&C Publishers, 2008), *Gear Cutting Tools: Fundamentals of Design and Computation* (*CRC* Press, 2010, 2nd edition 2017), *Precision Gear Shaving* (*Nova Science Publishers*, 2010), *Dudley's Handbook of Practical Gear Design and*

Manufacture (*CRC* Press, 2012, 2nd edition 2016), *Theory of Gearing: Kinematics, Geometry, and Synthesis* (*CRC* Press, 2012, 2nd edition 2018), *Geometry of Surfaces: A Practical Guide for Mechanical Engineers* (Willey, 2013, 2nd edition Springer, 2019), *Advances in Gear Design and Manufacture* (*CRC* Press, 2019), *High-Conformal Gearing: Kinematics and Geometry* (*CRC* Press, 2015, 2nd edition Elsevier, 2020), *Advances in Gear Design and Manufacture* (CRC Press, 2019), *Recent Advances in Gearing – Scientific Theory and Applications* (Springer, 2021) are among the recently published volumes. He has also authored and coauthored about 350 scientific papers and holds over 260 patents on invention in the field, both US patents and international patents.

Michael Storchak (editor) is a senior researcher in mechanical engineering. He received his Dipl.-Eng. in 1974, Dr.-Eng. (Ph.D.) in 1984 in mechanical engineering, and Dr. Sc. degree in manufacturing engineering in 1994.

Starting 1997, Dr. Storchak works at the University of Stuttgart, Institute for Machine Tools (Germany). His research and scientific interests cover three areas: (1) gear machining, (2) metal-cutting processes, and (3) machine tools. In the field of gear machining, the main accomplishments by Dr. Storchak are as follows: (a) research, optimization, and synthesis of technological processes for gear finishing operations; (b) design and development of cutting tools with carbide alloys, and synthetic super-hard materials, (c) development of dressing tools with form periodic profiles, and (d) development of software for computing the design parameters of the profile and geometric parameters of cutting tools for gear machining.

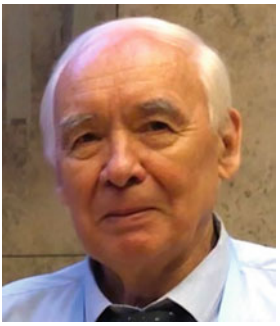
Dr. Storchak has authored a monograph and over 150 scientific papers published in top-notch international journals. He also holds over 50 patents on inventions.

About the Contributors

Vladimir B. Algin is a Professor of Mechanical Engineering. He received his Ph.D. in 1979 and Dr.(Eng)Sc. in 1995. Dr. Algin has extensive research experience in power transmissions with application in vehicles and tractors. He has developed numerous techniques and software for modelling basic properties (kinematics, dynamics, dependability) of mobile machines and their transmissions. His main research interest is "Lifetime mechanics of machines." This direction considers machine and their units as technical complex items, and investigates their functional properties and dependability on interconnected models, integrates and provides communication of multibody dynamics, strength mechanics, reliability theory, as well as system theory and computer technology. The obtained by Dr. Algin results of the research and development are used in Russia, Belarus, EC, Turkey, South Korea.

Dr. Algin has authored and coauthored over 380 scientific publications, including 11 monographs and about 60 patents on inventions and certificates on computer programs. Dr. Algin is the key developer of several State standards of USSR and Belarus. GOST 27.301–83 "Reliability in technique Prognosis of product reliability during designing. General requirements," STB 2466-2016 "Dependability in technics. Dependability calculation of technically complicated items," STB 2578-2020 "Dependability in technics. Estimation of lifetime expense for technically complicated items,"

are among them. He is also a member of the editorial board of several scientific international journals in Belarus, Russia, China, and Georgia.



Dmitry T. Babichev was a Professor of Machines and Mechanisms Theory, and a Professor in Mechanical Engineering. He graduated from the Irkutsk Technical University in 1962 as engineer with the qualification in *Manufacturing Technology, Machine Tools and cutting Tools*. He received a Ph.D. degree in 1972 and Dr. Sci. in 2005 in Mechanical Engineering. Since 1964, he worked at the Tyumen Industrial University, Department of Machine Elements. Professor Babichev was a well-known expert, and one of the leading theoreticians in Russia in the field of the mechanism science. He spent 58 years for his scientific and pedagogical work. Professor Babichev has authored three monographs, and over 150 scientific papers; he also holds three patents on inventions in the field of mechanical engineering.

Lots of Dr. Babichev's efforts were focused on the development of a new branch in the gear science – the theory of real gearing. In this theory the functional tooth flanks are generated by the real cutting tool, that is used to cut the gear. Dr. Babichev used different sets of normals to the surface generation near the tool cutting edge (wedge of normals, fan of normals and bunch of normals) aiming to describe the formation of the tooth lateral sides. The main scientific problem, on which he worked for over 50 years, is the development of kinematic methods of the gear theory and the shaping theory through the use of new geometrical, kinematic concepts and energy indicators.

Professor, Dr.Sci. Dmitry T. Babichev suddenly passed away on November 4, 2020.

Yurii M. Danylchenko is a Professor of Mechanical Engineering, Head of the Department of Machine Design, Igor Sikorsky Kyiv Polytechnic Institute (KPI). He received the degree of specialist in 1982, Ph.D. in 1987 and Dr. Sc. tech. in 2004. Dr. Danylchenko has an extensive experience studying processes and technological equipment for complex geometry parts machining, including gears. His main scientific interest lies in the field of kinematics of forming and metal-cutting machines kinematic structure, in particular – with an emphasis on the contribution of elastic systems components deformations of machines on machining accuracy.

Dr. Danilchenko has authored a monograph *Precision Spindle Assemblies on Rolling Bearings (Theory and Practice)* (NTUU KPI, 2003). He is the author and coauthor of 30+ scientific papers and patents on inventions in the field of gear cutting.

Andriy O. Hnatiuk is an Associate Professor of Mechanical Engineering. He received his M.Sc. in 2011, Ph.D. in 2019. Dr. Hnatiuk has experience in gear design and gear manufacture. The main research interest of Dr. Hnatiuk is the field of gear designs, methods and technologies of manufacturing gears, particularly with focus on the development of methods, technologies, designs of tools for the manufacture of working profiles of gerotor gears and sinusoidal gears.

He has authored and coauthored over 13 scientific works and patents on inventions.

Ihor E. Hrytsay is a Professor of Manufacturing Engineering. He received his M.Sc. in 1974, Ph.D. in 1983, and Dr.(Eng)Sc. in 2003. The range of scientific interests is the gear technology and a systematic and complex investigation of numerous problems and phenomena accompany tooth-forming and cutting processes. Among these – modeling of parameters of cut layers, cutting and friction forces, heat and wear of tools, contact interaction of tooth surfaces, and strains, dynamics of cutting processes and fluctuations of elastic systems of machines, patterns of forming, accuracy and quality

of generated surfaces, contact tension, load capacity and fatigue life of gears transmissions.

He has authored and coauthored 9 monograph and textbooks, holds 30 patents on inventions, and over 190 scientific papers.

Oleksandr M. Krasnoshtan graduated in 2004 from the Vinnytsa National Technical University with a degree of Mechanical engineer in "Automobiles and transport management.. He defended his Ph.D. thesis on "Modeling and determination of the main characteristics of a car transmission based on a gear-lever variator" in 2007. Since 2008 he has been working as Associated professor in National Transport University in Kyiv.

Olexandxer Krasnoshtan proposed to use the general algorithm for solving the problem of complex structural-parametric optimization of multi-operational technological systems in sphere of transport systems. He developed theory of using the gear-lever variator in construction of vehicles. Dr. Krasnoshtan is author of over 30 scientific papers, including 5 patents on inventions.

Anatolii V. Kryvosheia is a Doctor of Mechanical Engineering. He received his master's degree in 1971, and Ph.D. in 1981 in mechanical engineering. Dr. Krivosheya works at the Institute of Super hard Materials of the National Academy of Sciences of Ukraine, and deals with the design of tools made out of super hard and other modern tool materials for processing complex-shaped products, including for gears of different classes and types. He has extensive experience in designing gear cutting tools using shaping theory, affine space mapping theory, set theory, and gear manufacturing. The main research interests of Dr. Krivosheya are related to the kinematics and geometry of gear shaping, in particular, with an emphasis on precision machining of gears by a group of sequentially working tools, taking into account their regrinding, as well as the design and processing of precision gears for low-noise transmissions of cars, trucks, tractors, etc. aerospace engineering.

He is a coauthor of the one monograph, and the author and coauthor of 150 articles, including 22 patents on inventions.

Yuliia V. Lashyna holds a Ph.D. degree in engineering. She is an associate professor at the Manufacturing Engineering Department of the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute." She received her M.Sc. in 2008, Ph.D. in 2011, all in Manufacturing Engineering. Her main research interests are as follows: Concurrent Engineering, Design for Manufacturing and Assembly (DFMA), Automated Assembly Process Planning. Since 2010 she trains engineering students at the University.

Yuliia Lashyna is the author/coauthor of more than 30 scientific publications and holds 3 patents on inventions in the field of Manufacturing Engineering. She has coauthored a handbook *Technology Transfer in the Field of Energy Efficiency and Renewable Energy Sources* (Stuttgart: Steinbeis-Edition, 2014).

Sergey Yu. Lebeded received his Dipl.-Eng. in 2018 in the field of lift and carry, building and road means and equipment. Since that time, he has been working in the Department of Transport and Technological Systems of the Tyumen Industrial University as an engineer and later as a postgraduate student.

Scientific interests and research areas Sergey Yu. Lebeded are in the field of gearing geometry and kinematics. He develops mathematical models and software-implemented algorithms for the analysis of the plane gears geometry and the cylindrical gears synthesis, based on the definition of the engagement lines in the face section. Mr. Lebedev is the author of 28 scientific articles and holds 2 patents on inventions. Winner of a scholarship from the President of the Russian Federation and the Governor of the Tyumen Region.

Boris A. Lyashenko is a Professor of Mechanical Engineering, a specialist in mechanics of materials and coatings and in the field of structural strength. He received his M.Sc. in 1955, Ph.D. in 1964, and Dr. Eng. Sc. in 1977 – all in mechanics of materials and structural strength.

Dr. B.A. Lyashenko works in the field of mechanical engineering at the G.S. Pisarenko Institute for Problems of Strength of the National Academy of Sciences (NAS) of Ukraine, where he heads the Laboratory of Strengthening the Surface of Structural Elements. Dr. Lyashenko developed a theory of the ultimate state of heat-resistant coatings, a number of criteria for the optimal ratio of adhesive strength and other characteristics associated with the technology of coating, its nature and structure. He initiated a new direction in the process management of coating technologies and their optimization according to the strength criteria. He became a laureate of the State Prize of Ukraine in the field of science and technology (2001) and Honored Figure of Science and Technology of Ukraine (2002).

Dr. Lyashenko is a professor at the National Aviation and Transport Universities. He has trained 6 doctors of science and 20 Ph.D. students. B.A. Lyashenko has authored and coauthored about 350 scientific papers, including scientific monographs, state standards, holds about 100 patents on inventions (Soviet Union, Ukraine, Europe, USA, Japan, China, etc.).

Volodymyr Y. Melnyk is a leading researcher at the State Research Institute of the Ministry of Internal Affairs of Ukraine. He received his master's degree in 2003 and Ph.D. in 2013 in Mechanical Engineering.

He develops computer-aided design (CAD) software packages for gear cutting tools and gears. His main research is related to the kinematics and geometry of shaping of gears, in particular, with an emphasis on the finishing of gears, taking into account forward and reverse shaping. He is the author and coauthor of 70 publications, and holds 6 patents on inventions.

Yaroslava O. Mozghova is Associate Professor and a specialist in foreign philology and technical translation. She received her M.Sc. in 2005, Ph.D. in 2011, Associate Professor in 2013 and for over 10 years has been working as a lecturer in the Department of Foreign Philology and Translation at the National Transport University. Dr. Mozghova trains engineering students in communicative English. Students trained by her work in various industries where there is a need to communicate with professionals of foreign firms. Her main research interest is in the field of technical translation and expressive stylistics, with a focus on expressive syntax. Dr. Mozghova has authored and coauthored about 50 scientific papers, textbooks and manuals, including a textbook for engineering students *English Manual – Introduction to University studies with extensive readings related to transportation* (NTU, 2013).

Oleksandr A. Okhrimenko Doctor of Technical Sciences, professor of the Department of Machine Design the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" since 2019. He received his master's degree in 2001, Ph.D. in 2004 and Dr. Sc. tech in 2012. Dr. Okhrimenko is chef of the integrated manufacturing engineering department of National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute." His professional activity area is Design and automation of the manufacture of tools, technologies for the manufacture of parts for general mechanical engineering and aviation technology, design of mechanical engineering structures gear, gearbox, digitalization of machine-building production. He has authored and coauthored one monograph, and a textbook.

Vitalii A. Pasichnyk DSc Professor, Vice-rector for scientific work of National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute," Ukraine.

Prof. Pasichnyk is a Full Professor in the Department of Machine Design of National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute". His research interests are related to computer-integrated manufacturing engineering, computer-aided processes planning and advanced manufacturing engineering. Prof. Pasichnyk is scientific adviser of the research group working with advanced technologies of digital manufacturing. He is a member of Administer Committee of the National Council of Ukraine for Science and Technologies Development. Vitalii Pasichnyk is the author/coauthor of over than 180 scientific publications, and holds 15 patents on inventions in the area of Manufacturing Engineering.

Sergii Pasternak received his M.Sc. in 2006 and Dr.-Ing. in 2016 in mechanical engineering. He has experience in gear design and gear manufacture, development of hybrid clamping systems, design of cutting tools made of alternative materials and optimization of the machine tool structure by using neural networks. His main research interest is the field of kinematics and geometry of gearing, particularly with a focus on design and optimization of machine tools and machining of gears with profile-independent disc tools. Dr.-Ing. Pasternak has spent about 16 years developing software (CAD and CAM tools), hardware and processes for gear design and manufacturing. He has been training engineering students at universities for 10 years. Since 2016, he works almost completely for industry.

Dr.-Ing. Pasternak has authored one monography and also authored and coauthored about 30 scientific papers, and holds 2 patents on inventions in the field of the gear cutting.

Eduard K. Posviatenko is a Professor of Mechanical Engineering, a specialist in the field of applied mechanics and engineering technology. He received his M.Sc. in 1964, Ph.D. in 1974, and Dr. Eng. Sc. in 1993 in the field of mechanical engineering technology. Since 1997 – Honored Worker of Science and Technology of Ukraine.

More than 50 years of research E.K. Posvyatenko devoted to machine-building technologies, in particular broaching, metal-cutting tools, materials science, surface engineering of machine parts, history of science and technology.

Dr. Posviatenko has extensive experience in implementing scientific research in industry. For about 30 years he has worked at the V. Bakul Research Institute for Super hard Materials of the National Academy of Sciences of Ukraine on the problem of machinability using cutting at low and medium speeds, facilitated training of highly qualified specialists for industry, research and educational institutions, conducting their certification in the department of the Cabinet of Ministers of Ukraine.

Professor E.K. Posviatenko is currently a professor in the Department of Manufacturing, Repair and Materials Science of the National Transport University (Kyiv), has supervised and trained 6 Ph.D. and 2 Doctor of Sciences students. Dr. Posviatenko is the author and coauthor of 425 scientific and academic papers, including monographs, handbooks, manuals and over 50 patents for inventions (Soviet Union, Ukraine, Germany, Great Britain, France, Japan, Czech Republic).

Nataliia I. Posviatenko is Associate Professor and a specialist in the field of mechanical engineering, machining of materials. She received her M.Sc. in 1986, Ph.D. in 2005, Associate Professor in 2005, and for over 20 years has been working as a lecturer at the technical universities of Kharkiv and Kyiv.

For about 35 years her research interests have been related to the formation of complex surfaces, cutting super hard materials, surface engineering, tool materials, the history of science and technology, as well as mechanical engineering, including the synthesis of load lifting machines.

Dr. Posviatenko is the author and coauthor of 150+ scientific works, including monographs, textbooks, scientific articles in publications in Ukraine and abroad, teaching materials: "Essays on the history of applied technical sciences in Ukraine."

Stephen P. Radzevich is a Professor of Mechanical Engineering, and a Professor of Manufacturing Engineering. He received his M.Sc. in 1976, Ph.D. in 1982, and Dr.(Eng)Sc. in 1991, all in mechanical engineering. Dr. Radzevich has extensive industrial experience in gear design and gear manufacture. He has developed numerous software packages dealing with computer-aided design (CAD) and computer-aided machining (CAM) of precise gear finishing for a variety of industrial sponsors. His main research interest is the field of *Kinematics and Geometry of Gearing*, particularly with a focus on precision gear design, high-power-density gear trains, torque share in *split-power-transmission systems* (*SPTS*), design of special purpose gear cutting/finishing tools, and design and machine (finish) of precision gears for low-noise and noiseless transmissions of cars, light trucks and so forth.

Dr. Radzevich has spent about 45 years developing software, hardware and other processes for gear design and optimization. Besides his work for industry, he trains engineering students at universities and gear engineers in companies.

He has authored and coauthored over 40 monographs, handbooks, and textbooks, about 650 scientific papers, and holds over 260 patents on invention in the field, both, USA patents and International patents.

Konstantin B. Salamandra is a leading researcher at the Mechanical Engineering Research Institute of the Russian Academy of Sciences (IMASH RAN). He graduated from the Russian State Technological University "MATI" in 2007 and qualified as an engineer in aircraft and helicopter engineering. He received his Ph. D. in the theory of mechanisms and machines in 2009. The main area of scientific interests of Dr. Salamandra is methods of analysis and synthesis of mechanisms with multi paths of power flow, planetary-layshaft transmissions, gear shifting.

He participated in the research project “The Analysis and Synthesis of Transmissions & EVTs” within the agreement on research cooperation between IMASH RAN and General Motors, was the head and executor of several grants from the Russian Foundation for Basic Research and the Russian Science Foundation.

He has published over 70 papers in scientific journals and conference proceedings, holds 16 patents on inventions.

Olexandr I. Skibinskyi is an Associate Professor of Mechanical Engineering. He received his M.Sc. in 1998, Ph.D. in 2005, all in mechanical engineering. Dr. Skibinskyi has experience in gear design and gear manufacture. His main research interest is the field of gear designs, methods and technologies of manufacturing gears, particularly with a focus on the development of methods, technologies, designs of tools for the manufacture of working profiles of gerotor gears (epicycloid and hypocycloidal gears).

He has authored and coauthored over 30 scientific works and patents.

V. E. Starzhinsky is a specialist in the Mechanism and Machine Science. He received Ph.D. degree in 1968 with specialization “Mechanics of Polymers,” Dr. Sci. in 1987 with specialization “Machine Science" and Technology of Mechanical Engineering" and Ass. Prof. in 2009 with specialization “Mechanics." His scientific interests lay in the field of Mechanics of Machine and their Components, particular basically in gears and power and instrument transmissions. The main topics of this scientific area concentrate at the gear technology, quality, accuracy, wear resistance, terminology including plastic gears. Victor E. Starzhinsky is the author and coauthor of more than 280 monographs, textbook, dictionaries and papers.

By Dr. Victor E. Starzhinsky large input in MMS Terminology have been made: he took part personally in the 19th-25th the Working Meetings of IFTOMM Permanent Commission “Standardization of Terminology on MMS” in 2000-2016, took part in elaboration of MMS Terminology at the Chap. 12. Gearings; 14.

Transportation Machinery and Logistics; 15. Quality factors of Machines and Their Components; 16. Compliant Mechanisms.

Under his editorship, a few editions of "Reference Dictionary Book on Gearing. Russian-English-German-French" (Publishing House MPRI NASB, 2002, the first edition only Russian-English-German; JSC "Svetoch," 2004, 2nd edition; BelGISS, 2005, 3rd edition; Publishing House MPRI NASB, 4th edition and 2011, 5th edition), have been published.

Under his editorship the Proceedings of Scientific Seminars "Terminology for Mechanism and Machine Science," BelGISS, 2010, MPRI NASB, 2015, have been reported.

He is one of the developers of Interstate Standard GOST 31381-2009 on the classification and description of gear failure modes adopted the of the national and international standards and normative documents: DIN, ANSI/AGMA, ZFN, "Gear Failure Analyses."

He also holds over 80 patents on inventions, and certificates on software (USSR, Russia, Belarus), supervisor and key person of above 20 national and international research projects on fundamental and applied investigations.

Michael Storchak received his Dipl.-Eng. in 1974, Dr.-Eng. (Ph.D.) in 1984 in mechanical engineering, and Dr.Sci. tech. in 1994 in manufacturing engineering.

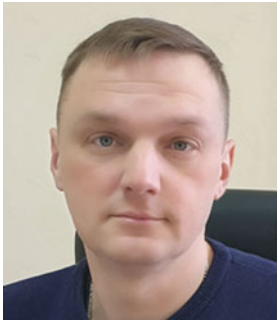
His research areas and scientific interests cover three main sections: gear processing, study of cutting processes and research in the state of metal cutting machines. In the field of gear processing, the main activities of Dr. Storchak are: study, optimization and synthesis of technological processes for gears finishing; design and development of cutting tools equipped with hard alloys and synthetic super-hard materials, development of dressing tools with complex periodic profiles, software development for calculating the profile and geometric parameters of tools for gear machining.

The results of research and development of Dr. Storchak are presented in one monograph, more than 150 scientific papers, and holds over 50 patents on inventions.

Mykola E. Terniuk graduated in 1972 from the Kharkov National Technical University "KhPI" with a degree of Mechanical engineer in "Automation and complex mechanization of mechanical engineering." He received his Ph.D. in 1976, and Dr.Sci. 1983.

Professor Mykola Ternyuk designed and introduced a general algorithm for solving the problem of complex structural-parametric optimization of multi-operational technological systems. Independently or with coauthors, he developed a number of new types of gears and technological equipment for manufacturing them, as well as the foundations of the theory of structures and design solutions for multi-parameter gears and gear variators. The revealed regularity of the structure of the Universe in the form of a System of periodic systems of structures of objects of the visible material World has been published. The type and place of the Periodic Table of Technical Elements in its structure has been shown. Based on above mentioned, he proposed an algorithm for a formalized directed synthesis of technical innovations.

Professor Ternyuk is author of over 700 scientific papers, including 250 patents on inventions.



Pavlo M. Tkach was Assistant Lecturer and, later, Associate Professor at Volodymyr Dahl East Ukrainian National University in the city of Luhansk, Ukraine. Now he is a Head of the Science Management Department at E.O. Paton Electric Welding Institute of the National Academy of Sciences of Ukraine in the city of Kyiv, Ukraine. He received the Ph.D. degree in 2004. Dr. Tkach has more than 100 publications, including coauthoring in four books those of *Highly Loaded Cylindrical Gears with Biconvex and Biconcave Teeth* (V. Dahl EUNU Publishing, 2005), *Intro to Machines Theory* (V. Dahl EUNU Publishing, 2009), *Short Course on Machine Elements* (V. Dahl EUNU Publishing, 2009) and *Machine Elements. Competitive Tasks* (V. Dahl EUNU Publishing, 2014). Also, he is the author of 15 patents on inventions. Currently, the main field of his research is focused on the wear resistance increase and strength improvement of spur gears using the non-standard teeth profiles.

Oleksandr V. Ustynenko is a Professor in the Department of Theory and Systems of Computer-Aided Design of Mechanisms and Machines, National Technical University "Kharkiv Polytechnic Institute" (NTU "KhPI"). In 1987 he graduated from Kharkov Polytechnic Institute, specialty "Wheeled and Tracked Vehicles." He worked at the Malyshev plant, a gear processing engineer-technologist and since 1991 he has been working at KhPI. Dr. Ustynenko received the Ph.D. degree in 2000. He has about 240 scientific and educational publications, including 11 authors certificates of the USSR for invention. Main scientific directions of Dr. Ustynenko lie in synthesis and research of gears with convex-to-concave contact, modeling the fatigue strength of gears, elaboration and research of two-parametric gears and Optimal design of transmissions for wheeled and tracked vehicles by mass and dimensions.

Borys S. Vorontsov is a Professor at the Manufacturing Engineering Department of the National Technical University of Ukraine “Igor Sikorsky Kyiv Polytechnic Institute.” He received his M.Sc. in 1980, Ph.D. in 1987, and Dr.(Eng)Sc. in 2018, all in mechanical engineering. Dr. Vorontsov has experience in gear design. He has developed software packages dealing with computer-aided design (CAD) of precise gear finishing. His main research interest is the field of Kinematics and Geometry of Gearing, particularly with a focus on precision gear design, high-power-density gear trains, and design of special purpose gear cutting/finishing tools.

He has authored and coauthored 6 textbooks. He also authored and coauthored about 150 scientific papers, and holds 10 patents on inventions in the field (Soviet Union and Ukraine).

Tianfeng Wang received his bachelor's degree from Liaoning University of Technology in 2019. Now he is studying for his master's degree in Northeastern University China under the guidance of Professor Yaping Zhao. His research interests include the meshing theory for gearing and the kinematical geometry for worm drives.

Yaping Zhao is a Professor of Mechanical Engineering in Northeastern University China. He received his M. Sc. in 2002 and Ph.D. in 2005, all in mechanical engineering. His research interests lie in Meshing Theory for Mechanical Transmissions, Research and development of novel types of gear drive, Engineering Differential Geometry and so on. His academic titles include: New Century Excellent Talent Awarded by Chinese Ministry of Education, Excellent Talent in Institutions of Higher Learning in Liaoning Province, Jianlong specially appointed professor of Northeastern University China, Leading talent of Shenyang, Promising Young Person of Science and Technology of University, etc. Dr. Zhao was a research fellow and a visiting scholar in Nottingham Trent University, England, and Northwestern University, USA, for 1.5 years in total. As corresponding or first author, Dr. Zhao has published about 30 papers. He was repeatedly rewarded for best paper by the academic community and government agency. He won China Production-Study-Research Cooperation Innovation Prize. Dr. Zhao holds 4 China patents on the worm drive invention. Dr. Zhao is a senior member of CMES and a member of ASME. He serves as the deputy chairperson of the TC of gearing and transmissions in IFToMM and the research grant proposal assessor in the field of gear drive for many institutes who manage the scientific research fund. He also serves as the reviewer for a number of international SCI journals, and the editorial board member of Mechanical Engineering Technology and Advances in Computational Design.