Preface to the Second Edition

In this second edition, all chapters are revised in which typos and errors are corrected; and comments and feedbacks are included. In addition, a few new topics on automotive turbochargers are added in this book.

First, the new CO_2 emission laws for passenger and light duty commercial vehicles in the European Union countries (EU) from 2012 to 2021 are discussed and some possible measures that should be carried out to comply with the new emission laws. Second, the turbo compound is used in normal and hybrid operations of commercial vehicles. Third, the new technique of three-stage turbochargers is applied for the first time to the passenger vehicle of BMW M550d. Fourth, the two-phase lubrication Reynolds equation with the bearing filling grade that depends on the bubble fraction of the oil mixture is used in the bearing computation. Fifth, the failure mechanisms of the bearings due to wears and fatigue are analyzed and displayed.

Furthermore, the new Chap. 10 deals with designing the platforms of automotive turbochargers using physical similarity laws. The platform design is based on the market analysis of the engine requirements and the strategy for the type series of the platform. Then using the similarity laws among the turbomachines, downsized engines, and classical mechanics, the power characteristics and geometrical sizes of the turbocharger type series are computed for the platforms of passenger and commercial vehicles.

Rotordynamics of automotive turbochargers is a special case and the most difficult application in turbomachinery; therefore, it involves the broadly interdisciplinary field of applied physics and mechanical engineering. Hence, some mathematical backgrounds of vector calculus, differential equations, and bifurcation theory are required. This all-in-one book of turbochargers is intended for scientific and engineering researchers, practitioners working in the rotordynamics field of automotive turbochargers, and graduate students in applied physics and mechanical engineering.

I would like to thank Dr. Jan-Philip Schmidt and Mrs. P. Jantzen at Springer in Heidelberg for the helpful and cooperative work on the publishing of this book.

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Finally, my special thanks go to my wife for her understanding patience and endless support during the revisal of the second edition in my leisure and vacation time.

Ludwigsburg, Germany Hung Nguyen-Schäfer

Preface to the First Edition

This book has arisen from my many years of experience in the automotive industry, as a development engineer and as a senior expert in rotordynamics of automotive turbochargers. It is intended for senior undergraduates and graduates in mechanical engineering, research scientists, and practicing engineers who work on the rotordynamics of automotive turbochargers. It could be also used as a rotordynamic textbook in colleges and universities, and practical handbook of rotordynamics in the automotive turbochargers.

The topic of rotordynamics of automotive turbochargers is a widely interdisciplinary working field, first involving *rotordynamics* to study dynamics of rotating machines at very high rotor speeds as well as to balance the rotor. Second, it involves *thermodynamics* and *turbo matching* to compute working conditions of the turbochargers. Third, it involves *fluid and bearing dynamics* to compute the acting loads in the bearings at various operating conditions, and to design the hydrodynamic oil–film bearings. Lastly, it involves *applied tribology* to reduce bearing friction and wears of the journal and bearings. In order to understand the rotordynamic phenomena, readers are assumed to have some mathematical requisite backgrounds of modeling and simulating nonlinear rotordynamics of turbochargers. The author tries to keep the mathematics requirement as simple as possible in this book; however, without any mathematical background, it is quite difficult to comprehend and thoroughly understand the rotordynamic behaviors of turbochargers.

Exhaust gas turbochargers used in passenger, commercial vehicles, and off-road engines have some important discrepancies with the heavy turbomachines applied to power plants, chemical, and aeroplane industries. The automotive turbochargers are much smaller compared to industrial turbomachines. Therefore, they generally work at very high rotor speeds in various dynamically operating conditions, such as highly transient rotor speeds, variable pressures, high temperatures of exhaust gas, as well as unsteady-state mass flow rates of the intake air and exhaust gas. The industrial turbomachines are larger and heavier, and often operate at a nearly stationary condition. Due to the large compressor and turbine wheels, they operate at relatively low rotational speeds from 3,000 rpm (Europe) or 3,600 rpm (US) in power plants for electrical frequency of 50 or 60 Hz; up to about 15,000 rpm in chemical industries and aeroplanes. By contrast, exhaust gas turbochargers mostly work at high rotor speeds from 150,000 to 350,000 rpm in the automotive applications. Therefore, the unbalanced force is much larger than the rotor weight, leading to nonlinear characteristics of the oil–film bearings used in the automotive turbochargers. For this reason, nonlinear rotordynamics is usually applied to the turbochargers to study and compute the nonlinear rotor responses of the harmonic, sub-, and supersynchronous vibrations.

Moreover, turbocharger engineers in the industry have to confront many problems at once, namely good quality, feasibility, form tolerances in mass production, time to market (TTM), highly innovative products, and product price. The last one is an important concern for a company. No matter how good the products are, nobody can afford them because they are very expensive. Then, the question is, how long can the company survive without selling any product or always selling products at a loss. Parallel to the product price, turbochargers must be qualitative and innovative in terms of high efficiency, best low-end-torque, working at high temperatures of the exhaust gas, less or no wear of bearings, and low airborne noises. They should come to the market as soon as possible since the first bird gets the worm; i.e., despite highly innovative products, the time to market (TTM) is always shorter because the competitors never sleep. Additionally, the turbochargers should work in all operating conditions while they are produced at a possibly wide range of form tolerances in mass-production; e.g., radial and thrust bearings with large form tolerances since producing them with narrow ones increases the production cost, leading to rise in the product price.

All these boundary conditions make the turbocharger development in the industry much more difficult, especially in the nonlinear rotordynamics of turbochargers. Therefore, development engineers of turbochargers need to have deep understanding of rotordynamics and bearing systems containing radial and thrust bearings applied to automotive turbochargers. Furthermore, issues of rotor balancing and tribology in the bearings have to be coped with, so that the produced turbochargers work in any case at the given industrial development conditions. Customer requirements of the automotive turbochargers are very high, in terms of good rotordynamic stability, low airborne noises, less or no wear of the bearings at high oil temperatures, and an acceptable product price.

Despite all careful efforts, there would be some unpredictable errors in this book. I would be very grateful to get your feedbacks and hints of errors. For this reason, readers of this book need to have a thorough analysis before applying it to their individual applications, and take their own responsibilities for possible damages.

I like to thank the board of directors of Bosch Mahle Turbo Systems (BMTS), Dr. Knopf, Dr. Prang, and Mr. Jennes for their support and for allowing me to use some pictures of BMTS in this book. Especially, I learned a great deal from working with Dr. Engels on turbocharging. In addition, I am indebted to my colleagues at BMTS who supported me in technical discussions, and provided help in this book: Dr. Haiser; Schnaithmann; Ahrens, Kothe, and Kleinschmidt; Lemke and Kreth; Di Giandomenico (Bosch).

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Stuttgart, Germany Hung Nguyen-Schäfer

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