Series Preface

The gearbox is one of the most critical components of the automobile. Indeed, it is one of the most critical components of many mechanical systems including those used in aerospace, maritime, construction and agricultural systems, to name a few. The intricate combination of rotating gears, bearing and shafts interacting in a wide variety of modes results in a complex set of dynamics defining the performance of the gearbox. This performance directly drives the ability to transmit power from the engine to the wheels. However, these interactions can also result in a significant amount of vibration and noise which can affect ride comfort, systems performance and even the safety of the overall vehicle due to issues such as durability and fatigue.

The *Automotive Series* publishes practical and topical books for researchers and practitioners in industry, and postgraduate/advanced undergraduates in automotive engineering. The series covers a wide range of topics, including design, manufacture and operation, and the intention is to provide a source of relevant information that will be of interest and benefit to people working in the field of automotive engineering. *Vehicle Gearbox Noise and Vibration* is an excellent addition to the series focusing on noise and vibration issues stemming from the gearbox. The text provides an excellent technical foundation for noise and vibration analysis based on significant past research and development efforts, as do many texts in this area. What makes this text unique is that the author expands upon the classical analysis techniques to integrate and make use of the latest, state-of-the-art technologies and concepts that are in use today. Finally, throughout the book, real world examples are given to demonstrate the application of the various techniques in combination with each other, providing the reader with some excellent insight into what can be expected when employing the various noise and vibration concepts.

As is mentioned in the beginning of this preface, *Vehicle Gearbox Noise and Vibration* is part of the *Automotive Series*; however, gearboxes are found on a wide variety of other systems outside of the automotive sector. Thus, the concepts presented in this text are applicable across a wide variety of fields. Issues related to noise and vibration of gearbox components such as shafts, gears and bearings further extend the utility of the concepts presented to a wide variety of rotating systems such as turbo pumps, aircraft engines and power generation, to name a few. Furthermore, the pragmatic signal processing techniques that are presented in the text are applicable to any physical engineering system, making the utility of this book quite far reaching.

Vehicle Gearbox Noise and Vibration nicely integrates a set of topics that are critical to rotating systems. It presents some very pragmatic applications of those techniques with

real-world examples demonstrating the implementation of the presented concepts. It is state-of-the-art, written by a recognized expert in the field and is a valuable resource for experts in the field. It is a welcome addition to the *Automotive Series*.

Thomas Kurfess
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Preface

Many books deal with the calculation of gear geometry with respect to gear strength, selection of material, lubrication of teeth, alignment of gears and estimation of wear. However, there is less information available on how they are manufactured, and almost none is available on such details as the meshing cycle of teeth through the measurement of gearbox vibrations. The usual measurements of gearbox vibration and noise provide a frequency spectrum. The frequency spectrum does not give direct information about the meshing cycle. The first articles on the evaluation of toothmeshing in the time domain appeared about 25 years ago. In the frequency domain the responses of the loaded gears are separated from each other by different frequencies, but this does also have an impact on the time domain. The time course of vibrations becomes useful only when it is able to focus on a selected gear train and filters out the vibration responses of the other gear trains. This technique is known as synchronous filtration or synchronous averaging. Another name for it is signal enhancement. This method of signal processing requires the signal to be resampled synchronously with the rotational speed, which allows the angular vibrations during rotation to be determined.

A substantial part of this book discusses how the time domain analysis of the transmission unit is applicable to any rotating machine. This book also describes the practical measurement of angular vibration during rotation and how this is associated with the method of measuring transmission error of the gear train. However, many researchers, especially in the UK and the USA (for example D. Smith, R.G. Munro, D. Hauser) have already carried out this measurement.

The gearboxes of the vehicles do not operate at a constant speed or a constant load. The variable speed requires changes in the gear meshing frequencies to be tracked and spectral peaks which are excited by meshing gears or due to the resonance of the mechanical structure to be distinguised. This book describes how the run-up and coast down of machines can be analysed using the time-frequency representation a multispectrum. An alternative way to analyse the transient states is to use tracking filters such as quadrature mixing and the Vold-Kalman tracking filtration.

This book describes how to interpret the composition of the real cepstrum. The difference between the cepstrum of harmonics, odd harmonics and the set of harmonics which contain the sidebands of carrier components is demonstrated. The fundamental frequency of the harmonics and odd harmonics is related to the zero frequency, while the fundamental frequency of the harmonic components as sidebands is related to the carrier component frequency.

The main topic of the book is a description of the research work which was done to reduce the gearbox noise of a heavy-duty vehicle. There are two possible solutions for keeping a

transmission unit quiet. Introducing an enclosure for preventing noise radiation is the easiest one, but it has consequences, for example, low efficiency and maintenance difficulties. The more sophisticated and much more efficient solution is based on solving the noise problem at the source. It means introducing improvement aimed at the gear design and manufacturing, which results in the greatest reduction of noise level as is shown.

The final chapter of the book describes the process of deciding how to proceed when using the most effective noise control measures. The ratio of radiated noise power of the individual units such as engine, gearbox, axles and tyres to the overall noise level during the pass-by noise test of the vehicle is analysed. Based on the resulting statistics the effect of limiting the deviations during production is estimated. The need to increase the stiffness of the transmission housing has been demonstrated by measuring the vibrations at the different gear ratios. The final decision was to change the contact ratio of the gears from low (LCR) to high (HCR). To keep the radiated noise under control, the effect of load, the gear contact ratio and the tooth surface modification on noise and vibration are illustrated by measurement examples giving an idea of how to reduce transmission noise.

In addition to describing the noise problems of the vehicle gearbox the book is also a textbook of signal processing. The chapter which deals with the demodulation of the modulated signals is universally applicable to the diagnostics of machines. In particular, the described methods for the measurement of angular vibrations are not that well known and are waiting for further applications. The book contains the first detailed description of the Vold-Kalman order tracking filter.