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# Brake NVH:
# Testing and Measurements

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To my wife Shirley, without whom this book
and much else would not be possible.

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# Preface

This book is intended to serve as an introduction to brake noise and vibration testing and measurement for those new to the field. It should be useful to both those familiar with vibration and acoustics and those who are just entering the field. Those familiar with noise and vibration may want to skip or quickly scan the first chapter to go directly into the discussion of brake-related noise and vibration issues.

Despite many decades of work on the measurement of brake noise and vibration, the field has only become mature in the last eight to 10 years. During this period, standard test procedures have been established and some of the key issues to generating consistent results have been documented. This text summarizes the recent standards and practices that have led to successful measurements among investigators worldwide.

In Chapter 1, a brief review of noise and vibration is provided for those not familiar with the field. While this discussion is not a comprehensive course in noise and vibration, it does review the basic concepts and much of the terminology to be used throughout the text. Where possible concepts discussed are related to brake noise and vibration issues to make the material as relevant as possible.

A summary of common brake noise and vibration issues is provided in Chapter 2. The broad scope of brake noise issues is defined in terms of the frequency range and conditions leading to various kinds of brake noise. Several specific common brake noise and vibration issues are defined in detail. These detailed descriptions also serve to highlight the approach to be used throughout the text in defining measurements and the critical issues in consistent and reliable brake noise and vibration tests.

The instrumentation, transducers, and other technical details of brake measurement are described in Chapter 3. The critical considerations in selecting, configuring, and validating measurement systems and transducers are described in this section. In addition, background material is provide to explain why some of the common transducer types and analyzer settings are not appropriate for brake noise and vibration measurements.

Chapters 4 and 5 describe measurement practice in detail for laboratory and on-road measurements, respectively. In each chapter, measurement standards and examples of measurement results are used to illustrate best practices. Example results are used to highlight the common characteristics and how to analyze the results obtained. These chapters also contain extensive discussions of the available and commonly used test equipment and measurement systems to

illustrate the current capabilities and where different types of equipment can best be used.

The development of a standard for the measurement of brake pad damping and natural frequencies is described in detail in Chapter 6. This segment provides a detailed discussion of the issues and best practices in such a measurement. The reader is provided with a great deal of insight into the detailed issues in brake vibration measurement and its relevance to radiated noise.

Finally, Chapter 7 describes the current trends in brake noise and vibration measurements. This section highlights the upcoming modifications and test requirements for brake noise and vibration in both the laboratory and on the road. This discussion should be particularly helpful to those just beginning to develop new laboratories or considering future updates of their laboratories.

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First and foremost, the author is indebted to the students who have attended his brake NVH courses. Many of these students have provided invaluable feedback on the structure and content of the course that is reflected in this text. The input from these individuals is much appreciated.

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# Introduction

Brake noise has been a problem since the earliest of vehicles. Whether the mechanisms were leather against a wooden wheel, brakes acting on the wheels of early trains, or modern passenger car disc brakes, braking a moving vehicle requires the dissipation of large amounts of energy. In such a rotating system, it is inevitable that a small fraction of this energy is turned into vibration and potentially noise. With a sufficient sound radiating surface, even this small amount of energy can produce significant sound levels. When one is dissipating hundreds of watts of power, a few tenths of watts in vibration and noise may not seem significant. However, even this amount of sound power can result in sound levels of 100 dB or more.

As has been often observed, every vehicle in the movies exhibits brake squeal. Brake noise can be seen from several perspectives: For some, the occurrence of squeal is seen as welcome confirmation that the brakes are working. For others, brake noise can be a minor irritation. Yet for others, brake noise may be seen as an indication that the brakes are not working properly. In the worst case, brake noise may lead to returns to the dealer and warranty claims.

Since the beginning of mass production of the automobile, brake noise has been an annoyance and consequently there have been attempts to quantify and understand the noise. While instrumentation has been available for brake noise measurement since the 1940s, it took more than five decades to develop useful and reliable measurement practices.

While brake noise is a common experience for those who ride in or operate vehicles, it has proven difficult to recreate in the laboratory. Developing a test apparatus that can reliably reproduce brake noise is a difficult undertaking. One must recreate all the vehicle operating conditions and provide a sufficient controlled acoustical environment to measure the resulting noise. The first internationally recognized brake noise test standard was not published until 2001. Therefore the standards of measurement and instrumentation to be discussed in this text will be those developed in the period from 2001 to the present. The discussion that follows will deal with current practices and procedures for quantifying and understanding brake noise.