
Disc Brake Squeal

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Disc Brake Squeal

Mechanism, Analysis, Evaluation, and Reduction/Prevention

Frank Chen, Chin An Tan and Ronald L. Quaglia

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Preface

The braking process in an automobile involves the contact of metallic solids sliding against each other, which sometimes generates undesirable noise, vibration, and harshness. Brake noise causes discomfort to passengers and degrades their perceptions of the quality of the vehicle. With today's vehicles so refined and other types of vehicle noise significantly reduced, brake noise and vibration are becoming more perceivable by owners, leading to high warranty costs. With extensive research on brake noise already reported in the literature, the focus of this monograph is to provide a state-of-the-art summary on the modeling, analysis, and prevention of noise generated in disc brakes, generally called disc brake squeal. Since the early twentieth century, many investigators have examined this problem by analytical, computational, and experimental methods. With the advance of computers and laboratory equipment, significant resources have been devoted to reducing or eliminating disc brake squeal, as evidenced by the strong attendance at the recent Annual SAE Brake Colloquia. However, disc brake squeal remains an elusive problem, and there is not yet a method to completely suppress it.

Brake squeal is an annoying, usually single-tone, and high-pitched noise. The frequency at which it occurs may vary from about 1 to 20 kHz. This frequency range is divided into low (1 to 3 kHz), mid (3 to 6 kHz), and high (6 to 20 kHz), with the human hearing ability cut-off at about 20 kHz. Brake noise below 1 kHz is often characterized as groan, moan, or grind. This is caused by the sliding contact mechanics in braking, but it also depends strongly on the modal characteristics of suspension systems. Brake squeal can occur at any temperature and with or without the presence of humid conditions. When squeal happens only in the morning because of overnight brake environmental conditioning, it is often called morning sickness/squeal. A cold squeal tends to occur at low speed with low braking pressure. A hot squeal most likely occurs when a brake is cooling down after warm-up periods. These characteristics have been observed in laboratory and road tests, and engineers and researchers have made progress (though sometimes at an incremental pace) toward understanding squeal generation and developing an integrated, cost-effective approach to designing quieter brakes.

The modeling and analysis of disc brake squeal is a challenging multidisciplinary problem in mechanics at both macro- and microscopic levels, involving contact mechanics, nonlinear dynamics and vibration, acoustics, and tribology. From a nonlinear dynamics viewpoint, it is generally believed that brake squeal is a friction-induced, self-excited phenomenon. Despite the large number of design variables that may vary during braking processes and the complexity of the problem, significant advances have been made in

every aspect of research—from understanding the fundamental mechanisms of squeal to disc brake design optimization. While these results have been published in a wide variety of resources, there is no single volume that summarizes the state-of-the-art development and progress made by academic and industrial researchers. It is with this motivation that we decided to consolidate recent results in squeal mechanism, identification, analysis, test evaluation, design, and prevention by internationally renowned researchers and engineers, from both the academia and industry, into this collection.

The chapters of this book are arranged in the order of mechanisms and causes, modeling and analysis, testing and evaluation, and design and prevention strategies. An overview of mechanisms of brake squeal is summarized in the first chapter, with emphasis on recent developments. Modeling of contact mechanics and dynamic analyses of brake squeal are given in Chapters 2 to 7. The analysis techniques include moving load and parametric excitation formulations, complex modal and nonlinear time domain analyses, and rotor mode characterization, with emphasis on the discussion of the instability of disc brake systems as the primary cause for brake squeal. Chapters 8 to 14 summarize the recent developments in brake pad damping design, brake dynamometer and road tests, laser metrology, and application of a state-of-the-art signal processing method—the Empirical Mode Decomposition (EMD) technique—to understand brake squeal. The EMD technique was developed by NASA and has been called one of their most promising technologies. Robust design approaches on brake squeal reduction and prevention are discussed in the last chapter. The book also collects more than 350 recently published literatures.

We would like to acknowledge the following contributing authors (listed alphabetically) for their efforts and willingness to share important data and information with the brake community. Of particular significance, we regret the loss of our dear colleague, Dr. Wayne Nack, who passed away in early 2005. We trust that his contribution to this monograph will reflect his long-lasting impact on the brake squeal research community.

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Though progress has been made in understanding and preventing disc brake squeal, much work remains ahead to achieve the ultimate goal of developing robust and effective strategies for squeal prevention through up-front design practice. We hope that this monograph will serve as a channel to promote and stimulate research in disc brake squeal among academic and industrial colleagues, and as a single volume to bring new researchers up to speed on recent developments in this exciting area of research. We would like to acknowledge the administrative staff of SAE in the publication of this work; their professionalism has allowed this monograph to be published in a timely fashion.

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