Investigation of the Relation Between Friction Material Abrasive Properties and the Squeal Noise Tendency in Automotive Disc Brake Systems

Luciano T. Matozo and Alberto Tamagna

Federal University of Rio Grande do Sul (PROMEC), Rio Grande do Sul, Brazil

Hazim A. Al-Qureshi

Federal University of Santa Catarina, Santa Catarina, Brazil

Ademir R. Menetrier and Paulo E. Varante

FRAS-LE S.A., Rio Grande do Sul, Brazil

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Automotive brake systems are very often susceptible to generating high-frequency noises as a result of a self-excited vibration. This phenomenon is generically referred to as brake squeal noise and is the subject of many studies which intend to identify and describe its exciting mechanism and to propose counter measures to avoid its occurrence. One key subject yet to be explored about squeal noise generation is the relation between friction material characteristics and its occurrence propensity. This work presents the development of an empirical equation obtained by dimensional analysis (Buckingham theorem) capable of linking the squeal noise occurrence with four main properties of the friction composite: abrasive hardness, particle size and concentration, and also composite compressibility. Experimental results were obtained by testing six different friction material formulations, in which the concentration of an abrasive or its hardness or its particle size was altered in order to explore the impact of these variables on the squeal noise occurrence. The noise generation was accessed by testing the friction materials using a standard disc brake system in an inertial dynamometer under a specially developed test procedure. The obtained results validated the proposed equation, which proved to be capable of identifying the squeal noise occurrence tendency.

NOMENCLATURE

d	—	particle size [μm]
H	—	abrasive hardness [HV]
H_{Zr}	—	zircon hardness [HV]
ε	—	compressibility [μm]
ν	—	volumetric content of abrasive [%]
π	—	squeal noise index
σ	—	standard deviation

1. INTRODUCTION

High-frequency noise caused by self-excited vibration in automotive brake systems, known as squeal noise, is an undesirable product of the braking process. Since the squealing sound is annoying to most passengers and drivers, it is usually associated with a poor-quality brake system.[1,2] This perception, although incorrect, negatively affects the image of the vehicle manufacturer, which motivated the search for alternatives to reduce or eliminate squeal noise occurrences. The most typical approaches to overcoming squeal noise problems consist of identifying and eliminating unstable vibration modes, inserting structural damping, or reducing the excitation forces generally associated with the stick-slip phenomenon.[3–6] In this scenario, the friction material used is a key factor for modifying the squeal generation pattern of a brake system due to its tribology behavior and impact on the topography of sliding surfaces.[7,8]

Due to the number of components in friction material formulations, sometimes more than 20 key ingredients in the tribologic pattern of a brake system must be focused on to make possible a study of the friction material composition and the squeal noise occurrence during brake stops. Within all categories of raw materials used on friction materials for brake system applications, hard abrasives are fundamental for the composite tribologic response.

In this study, two abrasives—alumina and zircon—with different hardness values, each one with two different grain sizes, were used as the single abrasive portion of standard light vehicle disc brake pad formulations. These formulations were used to generate samples with which the squeal noise occurrence tendency was verified by dynamometer testing. To establish the relation between the abrasive properties (i.e., hardness, grain size, and concentration) plus composite compressibility and the noise occurrence observed in the experimental procedure, a dimensional analysis, using the Buckingham theorem, was applied, resulting in a dimensionless index which is capable of representing the squeal noise tendency of a friction composite.[9]