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Analysis of the error in the estimation of the morphology of contact plateaus existing on the surface of brake pads

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ABSTRACT

The present paper provides a statistical analysis of the error obtained in the measurement of density (*Dcp*), size (*Scp*) and area fraction (*Acp*) of the contact plateaus existing on the surface of brake friction materials (BFM). Two different analysis were performed: (1) random: micrographs were taken in random locations of the BFMs' surfaces; (2) deterministic: micrographs were taken in 3 arrangements, that are border (B), center (C) and distributed (D). Results of the random analysis revealed that a micrograph area of 43.6 mm² (12 images) provides an error lower than 5% for all the 3 morphological parameters studied. Deterministic analysis showed that arrangement D provides the lowest error in *Acp*, while B and C are prone to generate biased errors.

Keywords: brake pad; contact plateaus; image segmentation.

Introduction

Automotive brake systems are responsible for reducing the vehicle speed by dissipating its kinetic energy. Beyond this main function, brake systems have to meet many manufacturing requirements, such as: friction performance, by maintaining a stable and sufficiently high level of coefficient of friction (COF); wear performance, by presenting a reduced wear rate; and acoustic comfort, by producing low level of noise and vibration [1-4]. These demands generally lay on the friction material (brake pad or lining).

In a brake system, the rotor is usually made of grey cast iron, which has good thermal properties, wear resistance, mechanical strength and damping properties with a competitive cost. Besides, grey cast iron is easy to machine [5-6]. Compositional modifications [7] and heat treatments [8] are also performed to improve the material properties of the rotor. Even others alloys, such as aluminum based [9-12] or titanium-based material [13], are sometimes used in replace of grey cast iron. However, disc material still remains with a simpler structure in comparison to the friction material.

The friction material (pad or lining) is a complex composite. More than 2000 different ingredients and their variants are now used in a brake friction material [14]. Up to 20 or 25 different ingredients can be added in a brake friction material [1,3,5,15-17], whose formulations can vary on type, nature, combination and amounts of ingredients [18]. According to the literature [3,5,13,18-22], typical components used in brake friction materials include: binder, fibers, friction modifiers (abrasives or lubricants) and fillers. These components can be composed by different materials, each one having a specific function [19]. The wide range of material combinations added in a friction material is reflected on its surface characteristics, which presents a very complex morphology and topography. For this reason, it is easy to understand how difficult is to find an optimal formulation for friction materials, i.e. a formulation which makes the brake pad or lining to be able to meet all manufacturing requirements (friction and wear performance, as well as acoustic comfort).

Morphology of friction materials has been described in terms of the characteristics (size, density and area fraction) of the contact plateaus [e.g. in 4, 5, 17, 23]. These contact plateaus (also known as hard patches) rise a few micrometers above the composite matrix and consist of flat areas [20], as a consequence of its contact against the brake disc or drum. The characteristics of the contact plateaus are influenced by the operating conditions, such as contact pressure, sliding velocity and temperature, as reported by [3] and [24]. The process of generation, growth and degradation of the hard patches are described in Ostermeyer's publications [3,15-16]. In those publications, it is reported that characteristics of the contact plateaus play an important role on brake performance.

Due to the technological development in the last decades, several techniques have been available to characterize the morphology and topography of the surface of brake friction materials. Examples of those techniques include: focused ion beam (FIB), confocal laser scanning microscopy, light interferometer,

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