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Comparison between methods for measuring wear in brake friction materials

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ABSTRACT

Three different techniques for measuring wear in brake pads are compared: a gravimetric method (electronic balance), a linear measuring touch probe method, and a three-dimensional laser scanning method. Laboratory-scale wear tests were performed on two different types of brake friction materials: a semi-metallic (SM) and a non-asbestos organic (NAO). All three techniques were able to show clear differences in the wear rates of the materials selected for study. It was observed that choosing only a few points of measurement in the thickness determination using a touch probe can lead to significant errors. These errors were higher than those caused by moisture absorption effects when using the gravimetric method. The laser scanning method proved adequate for investigating the wear profiles produced by braking tests. Results from the tests showed that SM material exhibits a higher coefficient of friction and wear rate than the NAO material. An increase of the contact pressure resulted in increased wear rates for both SM and NAO materials. The ratio between volume loss and mass loss also increased when contact pressure was higher indicating that samples had suffered from compressive deformation.

1. Introduction

Brake manufacturers utilize a combination of numerous ingredients (typically 5–30) aiming to optimize friction and wear performance of brake pads and linings [1,2]. As a part of a commercial truck or automobile, brake materials have many requirements, like resistance to corrosion, light weight, long life, low noise, stable friction, low wear rate, and acceptable cost vs. performance [1,3]. For this reason, develop a composition to meet all these requirements can be complex.

The complexity in developing a friction material for brakes is not only restricted to the material requirements itself. There are also some difficulties for accurately measuring the performance of the friction materials, especially the wear rate. It includes variability between wear results generated by different test machines, as showed by Blau and Jolly [4], and also some peculiarities and limitations inherent to each technique for measuring the wear of the brake materials.

An electronic balance and a linear measuring instrument are among the most common devices for measuring wear in terms of mass and thickness loss, respectively, as has been noted in many works, e.g. Blau and Jolly [4], Lee et al. [5], El-Tayeb and Liew [6], Deng et al. [7], Delgado et al. [8], Lee and Filip [2], Idris et al. [9], Lefanti et al. [10], Prabhu et al. [11]. Furthermore, both techniques and devices are recommended by international standard procedures for evaluating braking performance, such as ISO 26867 and SAE J2522 (AK-master).

The hygroscopic effect of the composite material can affect the mass loss measurements, especially when especial procedures in handling and storage are not adopted or a relatively low number of brakings is executed [5]. It can be considered an important inconvenience of the gravimetric method.

Linear measures of wear can be performed by any metrological technique, as described by ASTM Standard G99. In case of thickness measurements of a brake pad or lining, contact devices, such as vernier caliper, touch probe, micrometer and others are commonly employed. International standards for wear test procedure (e.g. ISO 26867 and NBR 14794) recommend to use at least 5 points equally spread on the brake pad surface for thickness measurements. This process becomes time consuming and prone to errors, which is a significant limitation, especially for the industry.

Irrespective of the contact devices, constructions based on optical phenomena are being developed for linear measures [12]. Advantages of those constructions are their higher accuracy than instruments based on mechanical contact [13]. Some authors have employed light interference microscopy for generating

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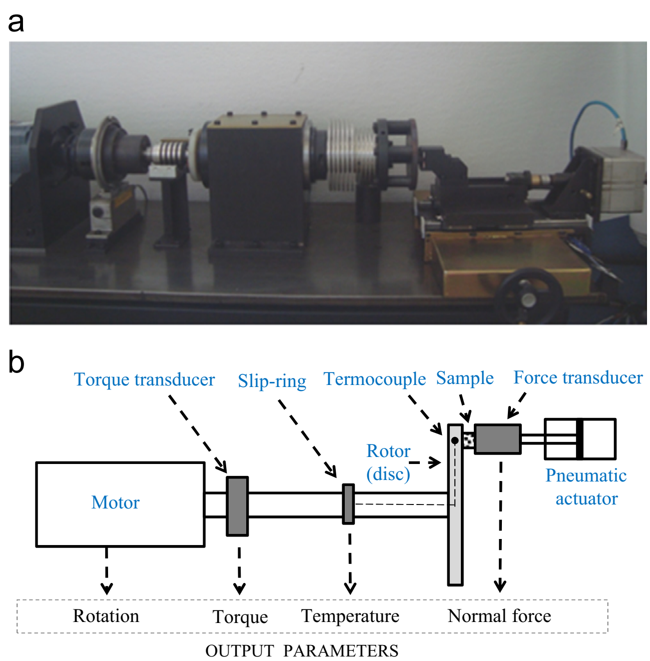

Fig. 1. Laboratory-scale tribometer: (a) digital photograph and (b) schematic.

topographic surface map (in three dimensions) of brake materials, e.g. in Bettge and Starcevic [13,14], Wieczorowsk [15]. By means of that technique, these researchers described characteristic properties of the contact, such as distributions of area, height and slope of the contact patches.

In the current paper, extensive experimental work (braking tests) was conducted in order to compare wear results obtained by gravimetric (electronic balance), contact (touch trigger probe) and optical method (3D laser scanner). Important aspects, limitations and advantages of every technique were carefully described. Besides, results of friction and wear rate are presented and discussed. Finally, the influence of the contact pressure on the wear resistance of two material compositions was also investigated.

2. Methodology

2.1. The laboratory-scale tribometer

Fig. 1 shows the experimental laboratory-scale tribometer used for conducting the wear tests performed in the current study. This test rig has been especially developed in order to characterize friction materials used as brake pads or linings. Precision of the friction measurements performed by the testing machine is ± 0.013.

2.2. Wear measurement methods

In this paper, wear of brake materials was measured by using 3 different devices: (i) touch trigger probe, (ii) electronic balance and (iii) three-dimensional laser scanner.

2.2.1. Touch trigger probe

The touch trigger probe (or simply touch probe) used in the current work consists of a ball type with an outside diameter of 3 mm. It has a repeatability (2σ) and resolution of ± 0.35 μm and 1 μm, respectively. This probe was attached to a coordinate measuring machine. By means of this instrument, thickness of the brake material samples was measured on 5 different points

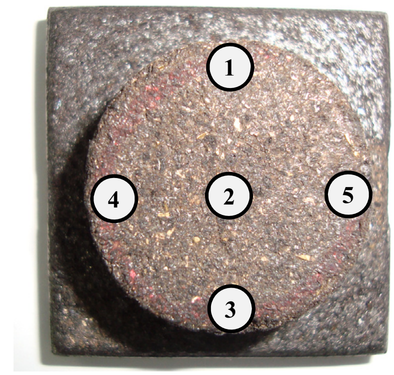

Fig. 2. Points measured by the touch probe on the brake sample surface.

(Fig. 2). This process was carried out before and after the braking tests. Then, thickness loss of every single location was determined by the difference between the measurements performed before and after the brakings. Finally, volume loss (or worn out volume) was calculated by multiplying the average of the thickness loss by the base area of each brake material sample.

2.2.2. Electronic balance

An electronic balance with precision of ± 0.2 mg was used for weighing the brake material samples. By subtracting the mass of each sample before and after the braking tests, it was possible to determine wear in terms of mass loss.

A previous investigation [5] has shown that gravimetric methods for wear measurement in porous materials like brake pads may be problematic. It is because the weight changes caused by moisture absorption of the composite material may be similar in magnitude to the weight changes caused by wear. Yet, according to that study, alternatives to mitigate this problem include: carry out much longer tests to increase wear and conduct special procedures in specimen weighing and handling, such as the use of atmosphere control, for instance.

In order to also investigate the effect of moisture absorption on the results of the mass measurements in the current paper, brake material samples were subjected to two weighing methods:

i). Dry weighing method: in this case, samples were allowed to remain in a heater at 100 °C for 24 h. After that, they were placed inside a desiccator containing a desiccant powder for 3 h. Then, the samples were removed from the desiccator and immediately weighed. Because moisture content was removed from the samples, this weighing process is identified as ‘dry weighing method’ in this paper.

ii). Moist weighing method: consisted of exposing the brake material samples 24 h to room air before weighing them, without any drying procedure. Temperature and relative humidity varied between 20–27 °C and 70–80%, respectively. As the samples are porous materials, they absorb moisture from the air. For this reason, this weighing process is identified as ‘moist weighing method’ in this paper.

Fig. 3 presents a schematic diagram of both weighing methods.

2.2.3. Three-dimensional laser scanner

The three-dimensional laser scanner (3D laser scanner) consists of a coordinate measuring machine coupled to a laser head. According to the manufacturer [16], when the light from the laser reflects off the measured object, the sensor recollects (some of) this light, polarizes it and puts it through a conoscopic crystal. The output from the crystal forms a diffraction pattern. The frequency