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Design, construction and performance of a novel brake pad friction tester

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ABSTRACT

Determination of the tribological behavior of brake pads under real environmental conditions is an important and critical task which can significantly impact the automotive industry. Most studies simulate or measure the variants by indirect methods and accept them as true results. The new computer-controlled, interactive brake pad friction tester presented in this study was developed for this purpose. The major components of the machine, which are operated simultaneously, include: a proportional pressure-controlled hydraulics power pack, a mechanical transmission system with electromagnetic clutch, and a brake and automation control with SCADA computer analysis interface. Compared to other friction testing machines, a very important innovation of the newly developed friction tester allows for the testing of the brake pad samples and measuring of the noise level both to be performed with high precision under real conditions. Moreover, this friction tester is capable of determining the friction coefficients; wear behavior, temperature, and life intervals of brake pad samples. This novel brake pad system is relatively cheaper and measures effective friction coefficients more accurately. **The uncertainty in measurements for friction coefficient and wear rate was approximately calculated as ± 0.0135 and ± 0.170 in all of experiments, respectively.** In this study, the machine performance was carried out to evaluate the friction behavior of non-asbestos brake pad samples reinforced with hazelnut shell powder according to the standard brake lining quality control testing procedure (SAE J661).

1. Introduction

A vast number of traffic accidents today can be blamed on problems related to the brake systems of the vehicles. Specifically, brake pads and the friction materials used in them are the most important components in the brake systems affecting driving security and braking performance [1]. In this regard, brake pads should meet the criteria of driving safety, comfort, and high strength and exhibit a constant friction coefficient, low wear rate, low noise and anti-vibration properties under adverse conditions [2,3]. Brake performance is affected not only by the materials and vehicle hardware design, but also significantly by driver behavior, the vehicle usage, the state of adjustment of the brake system, and the overall environment in which the vehicle is driven. In addition to these considerations, engine braking and the aerodynamics in the wheel system are possible influences on braking control systems. No laboratory test can simulate driving conditions precisely and accurately. In the literature, four different test methods for evaluating automotive brake pads and wear amount have been reported: (1) vehicle road tests, (2) inertial dynamometers, (3) vehicle sliding-pad tests and (4) laboratory tribometers. Among these, the tests conducted using laboratory-type friction devices are generally used. These test devices are of four types: (1) the friction assessment and screening test (FAST) machine, (2) the Chase-type machine, (3) pin-on disc tribometers and (4) inertial dynamometers (ECE R-90 standard test) [4–6]. The basic elements of these friction machines include a means to apply a force, use of conformal contact, and a means to measure frictional torque. Some tests involve constant speed, while others involve deceleration. The use of multiple-load applications is common, as is temperature measurement deceleration. Although a number of researchers are using the laboratory-type devices for determining the wear and friction characteristics of automotive brake pads composed of natural and metal powders, some researchers conduct their experiments by using the simpler friction devices designed for specimen-type pads. Qui et al. [7], Bahari et al. [8], Saffar et al. [9] and Matejka et al. [10] investigated the wear and friction performance of asbestos-free eco-friendly pads. The friction-wear properties of the prepared composites were tested by using a Chase friction performance testing device. For this type of device, the amount of wear and the friction coefficients were determined according to SAE J-661standard recommendations. On the other hand, some other researchers [11,12] tested these properties using FAST-type

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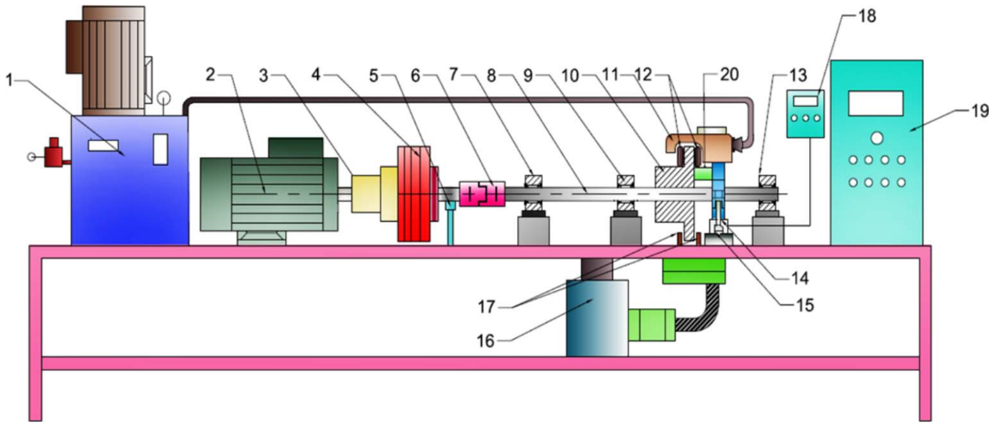

Fig. 1. Schematic diagram of the brake pad friction tester. **(1)** hydraulic unit, **(2)** AC motor-5.5 kW, **(3)** flange coupling, **(4)** clutch option, **(5)** clutch coils, **(6)** couplings, **(7)(9)(13)** bearings, **(8)** main shaft, **(10)** brake disc, **(11)** caliper, **(12)** brake pads, **(14)** caliper mounting apparatus, **(15)** load cell, **(16)** cooling unit, **(17)** heaters, **(18)** amplifier **(19)**, automation unit, **(20)** infrared laser pyrometer.

friction devices. Tayeb et al. [13], Kim et al. [14] and Liew et al. [15] conducted a number of studies on the determination of wear rate with regards to the friction coefficients and weight-loss of small brake pad specimens by using pin-on disc tribometers. This type of device was developed on the basis of the wearing of a material on a pre-determined path by an abrasive material. In their studies, Satapathy et al. [16], Kumar et al. [17], and Jang [19], carried out friction tests using brake dynamometers. Brake dynamometers are mainly Krauss-type advanced devices. In addition to wear, friction coefficients and brake forces, which the other devices can also measure, these devices determine the braking torque. More accurate and reliable friction coefficient results can be obtained by means of providing weight flywheels for the load on one wheel of the vehicle. Mat Lazim et al. [18] have investigated brake pads with different compositions by using small-scale friction testing device. However, the high cost and complex design requirements of these devices limit their usage. Domaç [20], Koç [21], Karaoğlu [22], Timur [23], Mutlu [24] and Kumar [25] developed special test setups for performing the wear and friction tests of specimen-sized pads which were compatible with international standards (SAE J661 and ECE R-90). These setups are computer-controlled and collect the test data by providing brake pressure with hydraulic drive; specimen-size pads are employed instead of full-size pads. These test setups are simpler and consist of fewer compounds in comparison with other types of setups, resulting in lower costs. As all of these tests are conducted on standardized specimens, they may not reflect the tribological response of real components designed with the same material. Recently, efforts for determining the wear and tribological behavior of materials have been centered on testing the full-size components under realistic conditions. Mazza et al. [26] constructed a unique and complicated test setup for investigating the tribological behavior of full-size commercial PTFE-based composites and compared the results with pin-on disc and thrust washer tests. The results of the two test devices were in good agreement.

Analysis of the above mentioned studies shows that the desired wear-friction values have been determined by means of the setups and standard devices developed for testing brake pads. However, some important drawbacks can be observed in the design, manufacture and use of these setups and devices, including inability to work with real pads and basic automation systems, inadequate data transfer systems, inability to provide an adequate vibration environment, insufficiency of required mechanical systems, and absence of interactive access. Thus, existing friction test setups and devices need to be improved in order to adapt to the rapid developments of the automotive brake pad industry. Therefore, in this study, the friction behavior of brake pads manufactured by using organic dusts was investigated by means of a newly developed brake pad test setup. The properties of this setup are superior to those of the existing ones as it is cheaper, able to turn out more reliable and accurate results, able to test real pads and can overcome all the aforementioned limitations.

This study had three primary objectives. The first was to present the development process of the new tester for brake pad friction coefficients and wear as suggested in the SAE J661 standard. The second objective was to test the new design with equipment similar to that used to evaluate the capability of friction testing machines. The third objective was to propose an experimental method for testing and evaluating new organic materials for use in brake pads.

2. Material and method

2.1. Design and development of new brake pad friction tester

For construction of this machine, it was necessary to consider the materials as well as the engineering properties of the clutch pads, and especially the physical and mechanical responses. The machine was designed with the strength and stability of the construction materials in mind so as to comply with the required all standards [2]. The schematic components of the brake pad friction tester developed in this study are shown in Fig. 1, including the general configuration for determining friction and wear behavior. The tester consists of 20 components and was designed according to the real friction and wear behavior influenced by contact of the brake pads with an automobile rotor disc. In this figure, a hydraulic unit with proportional valves directs the oil fluid which controls the open-close movements of the brake pads on opposite sides of the rotor disc by means of a piston. An electric motor (1440 rpm, 5.5 kW) was used to rotate the main shaft supporting a torque of 42.5 Nm and to transmit its motion to the rotor disc. The electro-magnetic clutch pad provides continuous transfer of power at the maximum torque value of the electric motor. The main shaft, 30 mm in diameter, is coupled to the motor and electro-magnetic clutch. The bearings help to guide the main shaft through the axis of the rotor disc. The rotor disc, made of gray cast iron and 240 mm in diameter, and the caliper act to slow down and stop the wheels. A load cell, mounted on the frame carrying the caliper pad assembly, is used to measure the friction force. The automation unit controls the simultaneous operations of the disc speed and temperature, contact pressure, friction force (weight in load cell), friction coefficients, braking time and applications, cooling fans and heaters. In addition, this friction tester is computer controlled and interactive with a SCADA analysis interface. Heaters on opposite sides of the rotor disc adjust the disc temperature to values in the range of 21–450 °C during braking applications. One of the two cooling fans decreases the temperature of the rotor disc, while the other cools the aluminum block of the electro-magnetic clutch pad. Furthermore, the temperature of the rotor disc is precisely measured by a non-contact infrared sensor made to measure the brake pad temperature. The analog output from the sensor is suitably signal conditioned and fed to the interface card of the computer to monitor and control the temperature at which the brake is to be applied. The metal table and blocks were manufactured from AISI 1050 steel. With this