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Dynamic behaviors of a wedge disc brake

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ABSTRACT

Mathematical models to study the dynamic behavior of a wedge disc brake are presented in this article. The friction coefficient has a significant role in the brake system dynamics especially, self-energized. A set of experiments have been conducted to formulate mathematical equations relating the friction coefficient, normal force and sliding speed. The effect of main operational parameters of a wedge disc brake such as normal force, sliding speed and wedge angle on the dynamic behavior and their comparisons with conventional disc brake system are investigated. Setting time and frequency response are the main performance indicators to investigate the dynamic behavior of a disc brake. The results indicate that friction coefficient significantly influence the resonance frequency and setting time of wedge disc brake shoe factor. However, the coefficient of friction has a negligible effect on setting time or resonance frequency of conventional disc brake. The effect of sliding speed on a wedge disc brake dynamics is somewhat considerable but it has a little effect on the dynamics of a classical disc brake. Moreover, the wedge angle has a considerable effect on the wedge disc brake dynamics. The normal force has negligible influence on dynamic characteristics of wedge and conventional disc brakes.

1. Introduction

Many researchers are trying to develop the vehicle disc brakes that may ensure better performance under severe service conditions. The expanding necessities identified with high safety, and better ride comfort of modern vehicles makes them turn out to be more perplexing. These high and principally assorted necessities are to a great extent thought about the car stopping mechanism, and specifically on its brakes [1–3].

Friction is the prime factor that may be considered for the dynamic behavior of disc brake systems. In uphill case, the braking process is basically a conversion of kinetic or potential energy into heat through friction. Many research works illustrated that the coefficient of friction is affected by several parameters such as the surface area topography, disc and pads properties, temperature, sliding speed, and normal force [4]. There were many efforts to accurately determine the coefficient of friction and its variation with normal force, sliding speed and contact temperature. This leads to the observation that the coefficient of friction is varying with the brake time. There exists a relationship between the sliding speed and the coefficient of friction especially under extreme loads. Many studies such as Blau [5] concluded that the sliding friction greatly increases with the decrease of the sliding speed. Also, it is observed that the coefficient of friction decreased with the increase of the sliding speed [6]. Blau [5] also researched to form the relation between the sliding speed and the coefficient of friction under extreme loads. The results indicate that the coefficient of friction decreases with the increase of the sliding speed. Eriksson et al. [7] have experimentally investigated the relation between the coefficient of friction and the sliding speed. They used five different types of brakes, and each brake had a trend that differed from the others, however, the coefficient of friction decreased with the sliding speed in all the brakes that were investigated in their study.

The brake shoe factor C^* is known as the ratio between friction (brake) force on the shoe to the applied force at the tip of the shoe. Whereas, the brake force between the rotor and the pad is as a result of the friction process, [8,9]. The shoe factor C^* depends mainly on the value of the coefficient of friction. The self-energized brakes are characterized by high brake shoe factor but at the same time they have high sensitivity to the friction coefficient variations. From the other side, conventional disc brake has low brake shoe factor but it is less sensitive to the change of friction coefficient [10,11].

Wedge disc brake is introduced in different shapes by many investigators such as Dietrich et al. [12] who invented it first,

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Fig. 1. Photo of brake dynamometer test setup and measurement instrumentation.

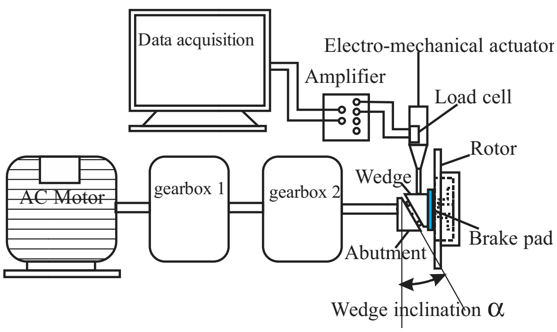

Fig. 2. Brake dynamometer test setup and measurement instrumentation.

and Hartmann et al. [13]. In any case, all the innovations that are introduced depend mainly on the providence of the disc brake with an electromechanical system as well as to apply the self-amplification in the disc brake, [14].

Many design forms of wedge disc brake were introduced to increase the brake effectiveness by changing its configuration. For example, an adaptive wedge disc brake is presented by Roberts et al. [15] which is provided by a variable wedge angle to maintain the brake shoe factor at constant and high values. In the last few years, many designs of wedge disc brakes were presented but until now they are still in the research stage. These designs are still at an early development stage and requires further investigation, [9,16].

Most of the previous studies used brake dynamometers to evaluate the brake performance. The brake dynamometer is the most famous mechanism that has been widely used to study the influence of different operational conditions mainly for good understanding of the brake system characteristics during braking process and at the same to present the better solutions, [17,18].

It is important to investigate the dynamic characteristic of vehicle's brake. For example, Ćirović, and Aleksendrić [19] have presented a study aimed to investigate the thermal and mechanical behaviors of disc brake using finite element analysis. Their results indicate that disc brake topography has a significant effect on dynamic characteristics as well as squeal generation.

Petry et al. [20] have investigated the effect of the brake disc waviness of the self-energized disc brake on its dynamic behaviors. Their results indicate that friction coefficient has a considerable effect on brake force and setting time. Also, Balogh et al. [3] have modelled self-energized disc brake to study its dynamic behaviors. Their results indicate that there was good validation between theoretical and experimental results. Moreover, the coefficient of friction has a significant role on setting time values.

In the present work, a set of experimental tests are conducted to formulate the mathematical equations to relate the coefficient of friction with sliding speed and normal force for wedge and conventional disc brakes. Then, Matlab Simulink models are created for wedge and conventional disc brakes to study their dynamic behaviors in terms of time and frequency responses. The main parameters of the evaluation are setting time that determines the

Table 1
Conventional and wedge disc brakes parameters.

Parameters	Symbol	Value
Piston arm mass, kg	m_a	0.033
Piston arm stiffness, N/m	k_a	10^7
Piston arm damping coeff., Ns/m	c_a	116
Brake pad mass, kg	m_p	0.2
(Wedge and brake pad) mass, kg	m_w	0.2
Brake pad damping coeff., Ns/m	c_p	89
Brake pad stiffness, N/m	k_p	10^6
Bearing mass, kg	m_b	0.2
Bearing damping coeff., Ns/m	c_{bx} and c_{by}	282
Bearing stiffness, N/m	k_{bx} and k_{by}	10^7

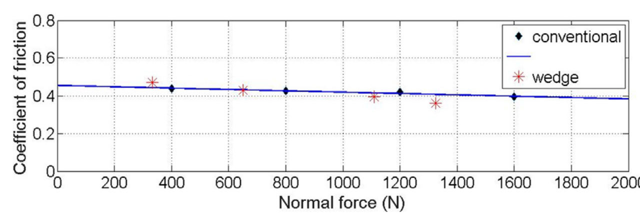

Fig. 4. Coefficient of friction variations with normal force.

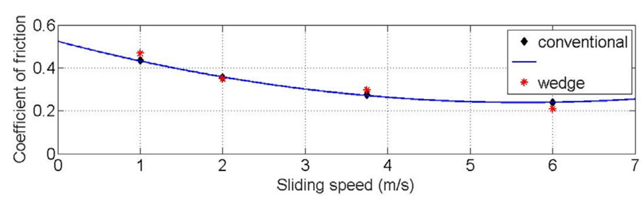

Fig. 5. Coefficient of friction variations with sliding speed.

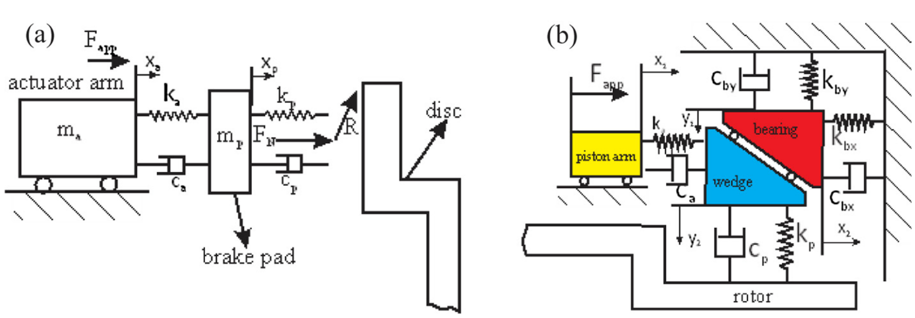

Fig. 3. Disc brake mathematical models (a- conventional b-wedge).

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