International Journal of Academic Engineering Research (IJAER)
ISSN: 2000-001X
Vol. 2 Issue 12, December – 2018, Pages: 6-9

Studying the Performance of New Wedge Disc Brake Mechanism

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Abstract: *The aim of this research is to investigate the ability of manufacturing and testing a new mechanism for wedge disc brake. The new mechanism consists mainly of the wedge itself, which is controlled by a gear set to change its inclination angle. The wedge is sliding on a surface controlling its inclination angle. The control of the inclination angle can change the factor between the applied force from the brake pressure source and the normal force to the brake pads. Changing the normal force to the brake pads can change the brake force on the rotor disc. The brake force from the pads on the rotor disc is the main goal in this research. The goal is to increase this force by increasing the normal force on the brake pads. The new mechanism was manufactured and tested experimentally in the laboratory by the use of a lathe machine carrying the mechanism for investigation. The results showed the ability of the new mechanism to increase the brake force by about seven times than conventional disc brake. The tested inclination angles were 45^o, 35^o, 25^o, 15^o, 12^o, and 10^o with different rotational speeds of 76, 150, 230, 305 rpm at different applied hydraulic pressure of 5, 7.5, 10, 12.5 bar. In all mentioned cases, the inclination angle of 12o was found to be the best angle in increasing the brake force.*

Keywords— Wedge disc brake; applied force; wedge inclination angle; brake force

1. INTRODUCTION

Brakes can be described as a tool to slow or stop the turning motion of the vehicle wheels through transforming kinetic energy to heat [1]. The drum brake and disc brake are the main two types of friction brake. Disc brake have many advantages than drum brake of that: fade resistance, self-adjustment, and freedom of pull. Therefore, drum brake systems for vehicles are being replaced with disc brake systems. It should be noted that the main disadvantage of disc brake system is non-occurrence of the self-energizing phenomenon [2]. Hence, so there were many efforts to modify the disc brake system that could be self-amplified. In wedge disc brake system, a great brake force can be achieved with small-applied force. There were many models of wedge disc brake systems according to applied force direction whether, is normal or tangential. It has different advantages such as improved ABS performance especially on slippery roads, continuous brake power distribution, shorter stopping distance, and environmentally friendly brake system [2]. Therefor new wedge disc brake will be investigated in this study. Coefficient of friction μ, which is between pads and rotor disc that presented by Coulomb's law, is defined as the ratio of brake force to the applied force. Many efforts were done to determine it accurately, for example, Blau [3], and Serverin and Dörsch [4], presented a friction law depending based on many parameters such as normal force, sliding speed, contact temperature and number of brakes. However, it has no exact trend with these working parameters. The ratio of the total brake force to the applied force is called as the characteristic brake factor C* which is considered as the main performance of the vehicle braking system [5]. It depends basically on the value of friction coefficient. Serverin and Dörsch [4] have presented the variation in the characteristic brake factor C* with different friction coefficients. They found that the characteristic brake factor is affected by friction coefficient μ variations with uneven impact, where the degree of influence of the friction coefficient μ on the characteristic brake factor C* is higher with the self-amplified brakes (drum and wedge) than with the conventional disc brakes. Wedge disc brake, which its mechanical model shown in Fig. 1, is an application of mechatronics in a new disc brake system. The concept of Roberts [6] was based upon the application of self-amplification action in the disc brake system by using a wedge mechanism. This mechanism is similar to the patent presented by Dietrich [7]. In this work, the researcher tries to find the optimal operating point. The characteristic brake factor C* is:

$$c^* = \frac{2\mu}{\tan(\alpha) - \mu}$$

Where, α is wedge inclination angle. They even considered using the operating point when the characteristic brake factor C* is infinity, i.e., the term tan(α) – μ becomes zero.

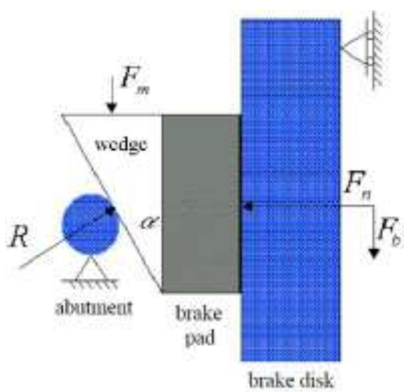

Fig. 1. *Mechanical model of wedge disc brake [8]*

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2. Description of Test-Rig

The test rig was built in order to generate the kinetic energy required for the system and then brake this energy by the brake wedge mechanism and measure the brake force at different speeds, applied forces, and different wedge inclination angles. The test rig consists of driving mechanism, flexible coupling, brake rotor disc, brake wedge mechanism, hydraulic connections for the brake fluid, and a measuring system for the brake force. The test rig is shown in Fig. 2.

The driving mechanism is mainly the gear box of the lathe machine to give the system the ability of working with different speeds. The driving mechanism is also having a flywheel to give the required inertia force for the braking system. The lathe itself is driven by an AC electric motor characterized by a constant rotational speed with maximum power of 10 hp (7.46 kW) at 1450 rpm.

(1)	Rotor disc	(5)	Inclination angle Control
(2)	New wedge disc brake	(6)	Coupling
(3),	Hydraulic press (a)	(7)	Measuring system
(4)	Hydraulic press (b)	(8)	Computer

Fig. 2. Experimental test rig

The brake rotor disc is the element for testing the brake force on it and it has a brake pads installed on it and connected with the brake wedge mechanism by the hydraulic connections. The new wedge mechanism is shown in Fig. 3.

The wedge mechanism is the most important part in the system, which consists of: two metallic parts have an inclined sliding surface between them has an inclination of 45^o, the lower part is connected to a gear driving mechanism to control the inclination of this part, the upper part is the wedge which is connected to the hydraulic connections from the applied force source and to the normal force on the brake pads which installed on the rotor disc.

The lower gear controlling the inclination angle of the wedge mechanism is driven by an electric motor with brake to adjust the inclination of the lower part of the mechanism as shown in Fig. 3. The sliding surface between the two parts of the wedge has a ladder bearing to prevent the friction between these two parts.

The hydraulic connection is the main part transferring the pressure from the hydraulic pedal to the brake pads. These connections take the pressure from the hydraulic pedal by means of a hydraulic press, this pressure is transferred to the wedge by another hydraulic press numbered 3 in Fig.2. After the wedge there are other hydraulic connections transferring the pressure from the wedge to the brake pads as shown in Fig.3.

After conducting the test and applying the brake force on the rotor disc, a measuring system for the disc braking force is installed to measure and record the brake force.

The applied force from the hydraulic pedal to the hydraulic press (a) at fig. (2) can be adjusted by using a pressure gauge with a control valve. The applied force acting from the hydraulic press (a) to the wedge moving it to force the hydraulic press (b) which generates the normal force at the hydraulic connection from press (b) to the brake pads. The normal force from the wedge is measured by a hydraulic gauge and recorded during the test

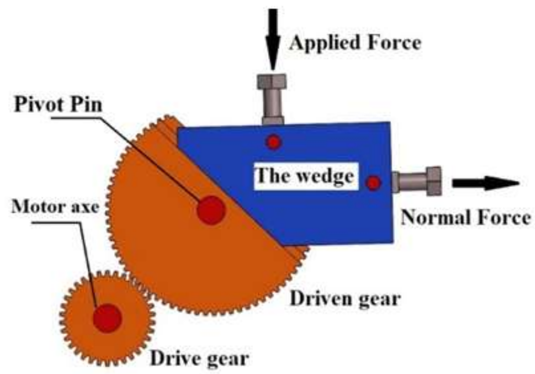

Fig. 3. *New wedge mechanism*

Measurement Instrumentation

The designed test rig with the measurement instrumentation is shown schematically in Fig. 4.

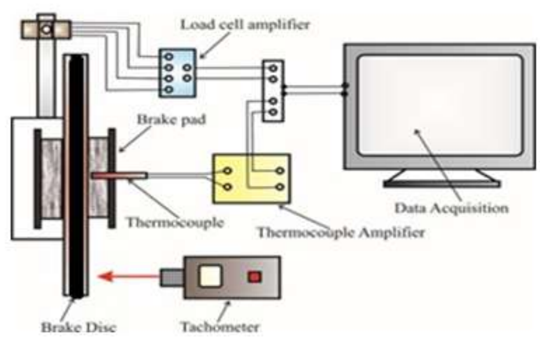

Fig. 4. *Schematic sketch of brake force, temperature and speed measurement instrumentations*

The instrumentation includes:

- Applied force measurement.
- Rotational speed measurement.
- Brake force measurement.

- Friction temperature measurement.

The applied force can be measured by a pressure gauge installed in the hydraulic line after the pedal. The hydraulic pressure of the brake fluid in the line can be multiplied by the area of the press (a) to obtain the applied force. The hydraulic press (a) and (b) pistons have a diameter of 40 mm. The applied force is adjusted to the required value by using a control valve.

The rotational speed of the lathe machine is adjusted to the required rpm and was checked also by the use of a digital photo tachometer.

The brake force is measured by a load cell (tension-compression load cell with 400 kg maximum load) which was installed beside the rotor disc and the force transmitted to it by means of a metallic connection was tightened to the rotor disc.

The temperature due to the friction was measured by a thermocouple mounted on the rotor disc above the brake pads.

The brake force and the temperature of the friction were recorded using a data logger transferring these readings to the computer to record it as shown in figure 4.

3. Experimental Work

The experiments were conducted to check the new wedge mechanism effect and to decide the optimum inclination angle for the wedge.

The selected parameters for the experiments were as follows:

The rotational speed (N) of 76, 150, 230, and 305 rpm.

The applied pressure (P_{app}) of 5, 7.5, 10, and 12.5 bar these values of pressure equals applied forces (F_{app}) of 628.572, 942.857, 1257.143, and 1571.43N respectively.

Inclination angle (α) of 45, 35, 25, 15, 12, and 10 degrees.

4. RESULTS AND DISCUSSION

Influence of Wedge Inclination Angle

The effect of the wedge inclination angle on the brake force is shown in Fig. 5. The decrease of the inclination angle from 45° to 12° increases the value of the brake force from 4788 N to 8400. N at P_{app} of 12.5 bar nearly 1.8 times. The results explain that increasing of the self-energizing action of the wedge brake with the decreasing of the wedge angle. Increasing the self-energizing action increases the normal force causing increasing the brake force. This is in agreement with Roberts [6] and Hartman [8]. But less than 12° nearly of wedge inclination causes a reduction of brake behavior due to the resistance of hydraulic press links (number 3 and 4 in Fig.2) to motion of the wedge.

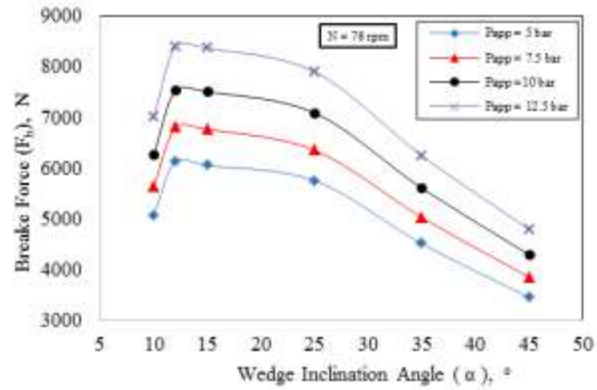

Fig. 5. *Effect of wedge inclination angle on the brake force at various applied pressures and constant rotational speed of 76 rpm*

Fig.6 shows that, the brake force fluctuates with no identical trend with the braking time. The variations of the brake force trend are a result of the friction coefficient trend fluctuations.

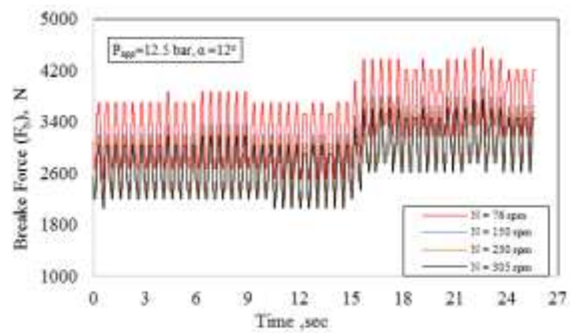

Fig. 6. *Variation of brake force with time at various rotational speeds and constant applied pressure of 12.5 bar with inclination angle of 12°*

Influence of Applied Force

The effect of applied force on the brake force, Coefficient of friction μ, and characteristic brake factor C* are shown in Fig. 7, 8, and 9 respectively. From the results shown, it can be seen that, the increase of the applied force cause a great increase of the brake force at all rotational speeds. The effect of the applied force obtain from the relation F_b = Normal * μ. When accruing an increase in the applied force, there is a decrease in the friction coefficient and hence the characteristic brake factor C* also decreases, this due to the increasing in friction temperature between brake pads and rotor disc.

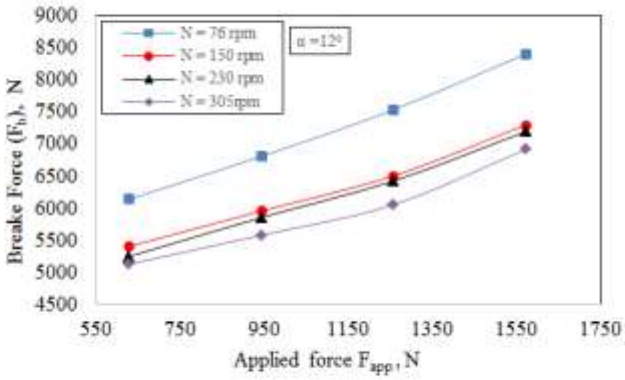

Fig. 7. *Effect of applied force on the brake force at various rotational speeds and constant wedge inclination angle of 12°*

Influence of Rotational Speed

From the results, it can be seen that the increase of the rotational speed causes a decrease of the brake force. Increasing the braking time leads to decrease the brake force especially at high speed. This is because of the increase of the friction temperature, which decreases the friction coefficient; therefore, the brake force tends to decrease.

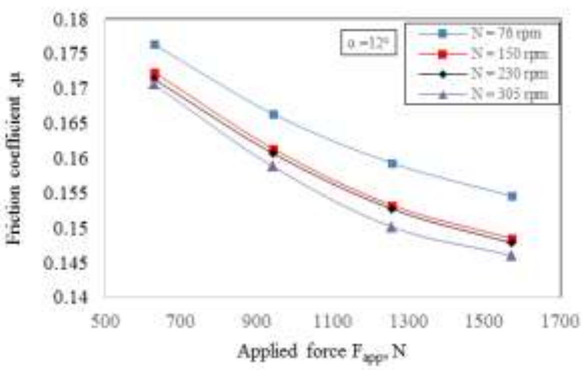

Fig. 8. *Effect of applied force on Coefficient of friction at various rotational speeds and constant wedge inclination angle of 12°*

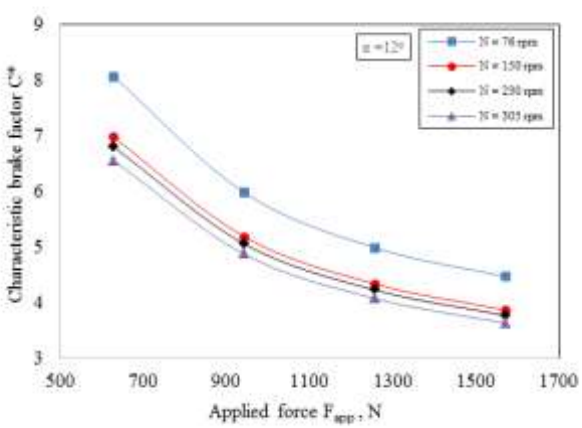

Fig. 9. *Effect of applied force on characteristic brake factor at various rotational speeds and constant wedge inclination angle of 12°*

5. CONCLUSION

The conclusions from the present study can be written as following:

(1) The increase of the applied force increases the brake force of the new wedge disc brake. The wedge inclination angle has a significant effect on the new wedge disc brake performances. The self-energizing action of wedge disc brake increases with the wedge inclination angle decrease.

(2) The higher the applied force the lesser the coefficient of friction and characteristic brake factor for wedge disc brakes.

(3) The brake force decreases with the increase of rotational speed due to the increasing of friction temperature.

6. ACKNOWLEDGMENT

The authors would like to thank Beni-Suef University, Faculty of Industrial Education for helping and supporting.

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