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Detection of Brake Shoe Lining Wear

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Abstract: During braking of the automobile the brake shoe lining wears. In many cases the brake shoe lining wear is not inspected periodically which leads to scoring of brake drum due to rivets in the brake shoe. Hence the optimal location for inspection is formulated by analyzing the brake kinematics and a sacrificial element (Transducer) is incorporated in system to be designed, which wears equally as the brake shoe lining producing a change in electrical parameter.

Key words: Vehicle inspection · Brake shoe · Wear measurement · Optimal inspection position

INTRODUCTION

Brake safety of a vehicle is one of the key points in the research field of active automobile safety. Brake shoe is normally used to ensure the car is operated in a controlled status by the friction movement between the quasi-static external surface of the shoe and the internal surface of the rolling brake wheel hub. When the brake friction lining thickness wears beyond the critical thickness the rivets comes in contact with the brake drum resulting in scoring of brake drum. For this reason, it is important to develop the accurate measurement method to monitor the variation in the thickness of brake shoe and determine the optimal inspection position for the sensor. In the presented study, a nonlinear variation of the wear loss along the brake shoe and the maximal abrasion is derived to determine the optimal location for installing the sensor. The scaled model of sensor designed is introduced to test the wear of brake shoe is determined.

Braking System: When a vehicle has been set in motion, the driver naturally is concerned that he or she is able to bring the vehicle safely to rest. [1] A brake system absorbs the kinetic energy of the vehicle mechanically or electrically in order to decrease its speed. In mechanical brakes, friction converts the kinetic energy into heat. In electric brakes, an electric current force a magnet to apply the brakes and thus the vehicle is brought to rest. This is the function of the braking system. The wheel cylinder pistons then apply force to the brake shoe, pushing them against the spinning drum and the friction between the shoes and the rotor causes a braking torque to be generated, slowing the vehicle. Heat generated by this friction is either dissipated through fins and channels in the drum or is conducted through the shoes, which are made of specialized heat-tolerant materials such as Kevlar or sintered glass.

Problems Due to Worn Brake Shoe: Brake safety of a vehicle is one of the key points in the research field of active automobile safety [2]. Brake shoe is normally used to ensure the car is operated in a controlled status by the friction moment between the quasi-static external surface of the shoe and the internal surface of the rolling brake wheel hub [3]. Many typical incidents of vehicles on express way are related to the disabled brake shoe as the friction layer on it is too thin to provide enough brake force.

▸ Damages Due to Worn Brake Shoe


Fig. 1: Worn brake shoe

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▸ Scored Drum

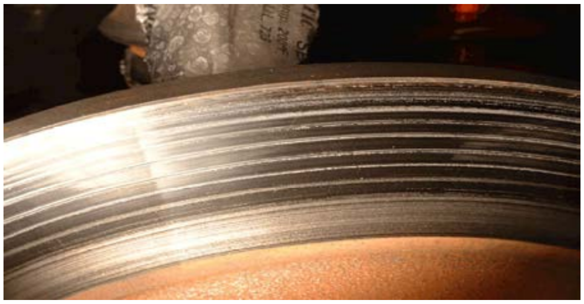

Fig. 2: Scored brake drum

▸ Excessive Wear and Galling

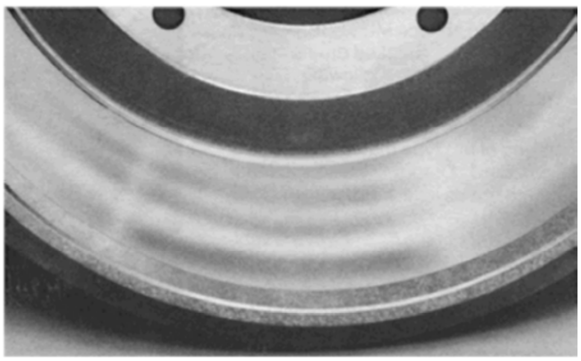

Fig. 3: Excessive wear and galling

Need for Brake Shoe Wear Indicator: The need for brake shoe wear indicator is very much significant because it is not easy to monitor brake shoe wear like in brake pads of a disk brake system [4]. Currently the only method of inspection of brake shoe friction lining thickness is by disassembling the entire wheel assembly, which is a time consuming process and cannot be performed periodically with ease. The life of the brake shoe friction lining cannot be fixed because it depends upon various factors. Some of the factors which influence the life of brake shoe friction lining are as follows.

- Driving condition of the vehicle
- Driving style of the driver

Brake Shoe Wear Indicator: The objective of the indication system is to provide the friction lining thickness of the brake shoe directly to the driver's cabin. The brake fiction lining wear measuring element is placed within the brake shoe assembly based on the following reasons,

- Can be adapted to any type of actuating mechanism
- Low cost for manufacturing
- Low cost for implementation
- Can be incorporated easily within the brake shoe

Determination of Maximum Wear Point: The position of the wear indicator should be located on the point with the largest radial displacement of a braking shoe to obtain maximum accuracy [2, 5]. Figure 4 is drawn to analyze the movement of the brake shoe. OA_1 is the original position of a brake shoe. O_1 is the center of the brake shoe OA_1. OA_2 is the active position of the braking shoe. O_2 is the center of the brake shoe OA_2. O is the rotary center of the brake shoe. δ is the angle between the original position O_1O_2 and x axis. æ is the rotary angle of the brake shoe. O_1P is a line section which is perpendicular to O_1O_2. P is the crossing point of O_1O_2 and OA_2. □ is the angle between O_1P and negative x axis. r is the radius of the brake shoe. Based on the geometrical relationship, the largest radial displacement of the brake shoe is generated on point P. Thus P is the optimal position for the wear inspection of the brake shoe. The vectors OO_1 and OO_2 can be respectively expressed by

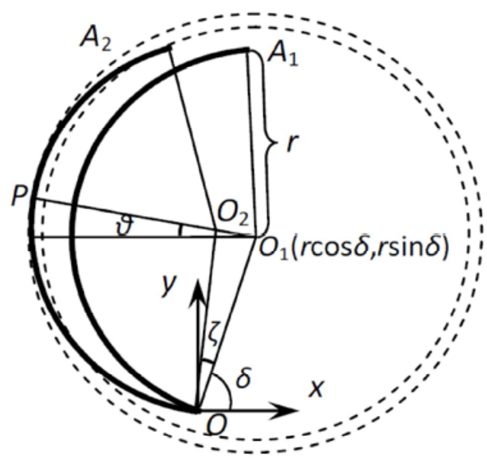

Fig. 4: Movement of the brake shoe

The brake shoe considered for experimentation has the following parameters

$\angle XOO_{1\delta} = 84°$
$\angle O_1OO_2 = 30°$

Radius of brake shoe **r** = 200mm

Representing the Point O_1 in Polar Form:

$O_1 = (X, Y)$
$= (r \cos \delta, r \sin \delta)$

X = r cos δ; Y = r sin δ

X = 200 cos84°

= 20.9057mm

Y =200 sin84°

=198.9043mm

O_1 = (20.9057, 198.9043)

By Applying Rotation Transformation in the Point O_1 about Z Axis:

O_2 =RO_1

where R is the rotational matrix about Z-axis

$$R = \begin{pmatrix} \cos\zeta & -\sin\zeta \\ \sin\zeta & \cos\zeta \end{pmatrix}$$

Let $O_2 = (x^{1,} Y^1)$

$$\begin{pmatrix} X' \\ y' \end{pmatrix} = \begin{pmatrix} \cos\zeta & -\sin\zeta \\ \sin\zeta & \cos\zeta \end{pmatrix}\begin{pmatrix} x \\ y \end{pmatrix}$$

$$= \begin{pmatrix} \cos 3 & -\sin 3 \\ \sin 3 & \cos 3 \end{pmatrix}\begin{pmatrix} 20.9057 \\ 198.9043 \end{pmatrix}$$

$$= \begin{pmatrix} 0.9986 & -0.0523 \\ 0.0523 & 0.9986 \end{pmatrix}\begin{pmatrix} 20.9057 \\ 198.9043 \end{pmatrix}$$

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} 10.473 \\ 199.71 \end{pmatrix}$$

$$O_2 = \begin{pmatrix} x'=10.473 \\ y'=199.71 \end{pmatrix}$$

O_2 = (10.473, 199.71)

The Slope of O_1O_2:

$$\tan \square = \left|\frac{y-y}{x-x'}\right|$$

$$\tan \square = \left|\frac{198.9043-199.71}{20.9057-10.473}\right|$$

$$\tan \square = \left|\frac{-0.8057}{10.4327}\right|$$

$\tan \square$= 0.77228

□ = 4.4160

Therefore O_1P is at an angle of 4.4160 to the horizontal.

Wear Measurement Method: The sensor is designed to fit within the thickness of the friction lining. The inner circuit consists of resistors (R_1, R_2 and R3…..R_7). Which are connected in parallel connection? The resistors used are made up of carbon composition. Carbon resistors are used because it can be made at low cost by the process of carbon resistive printing. Also a carbon resistor takes up very little space at the friction lining of the brake shoe so that the braking power provided by the friction lining is not reduced. The number of resistors connected in parallel depends upon the resolution of measurement, the more thinly printed carbon resistor the more the resolution of the measurement of the wear of friction lining of the brake shoe.

The output variation of resistance is produced as the each resistor wears out with the friction lining of the brake shoe. This output resistance is converted into voltage by means of a voltage divider circuit by adding resistor R_8, V_1 is the reference voltage and V_0 is the output voltage.

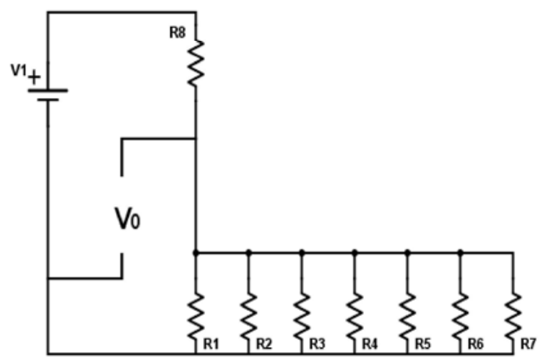

Fig. 5: Circuit of the sensor with voltage divider

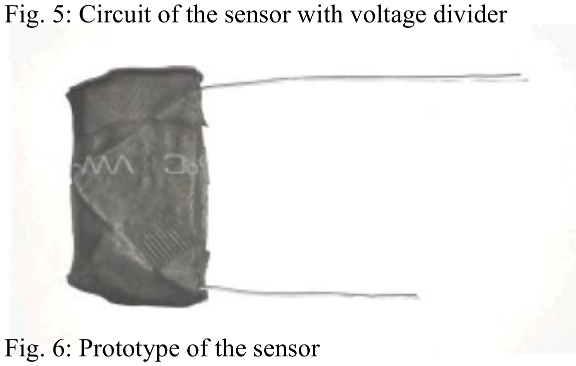

Fig. 6: Prototype of the sensor

The carbon resistor [6] used for the prototype is made with a resistivity of 2000 Ohm mm Length of each carbon resistor= 32mm Therefore resistance of each carbon resistor = 32*2000

R_1, R_2, R_3…..R_7 = 64000 Ohm

For 0% Wear:

$$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5} + \frac{1}{R_6} + \frac{1}{R_7}$$

R_{total} = 9142.8571 Ohm

For 20% Wear:

$$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5} + \frac{1}{R_6}$$

R_{total} = 10666.667 Ohm

For 80% Wear:

$$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

R_{total} = 21333.33 Ohm

For 100% Wear:

$$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2}$$

R_{total} = 32000 Ohm

For 120% Wear:

$$\frac{1}{R_{total}} = \frac{1}{R_1}$$

R_{total} = 64000 Ohm

$$V0 = V1 * \frac{R_{total}}{(R_8 + R_{total})}$$

R_8 = 7111.11 Ohm

Table 1: Output Voltage for wear percentage

Percentage of wear%	Resistance output Ohm	Output Voltage V
0	9142.86	2.81
20	10666.67	3.00
40	12800	3.21
60	16000	3.46
80	21333.33	3.75
100	32000	4.09
120	64000	4.50

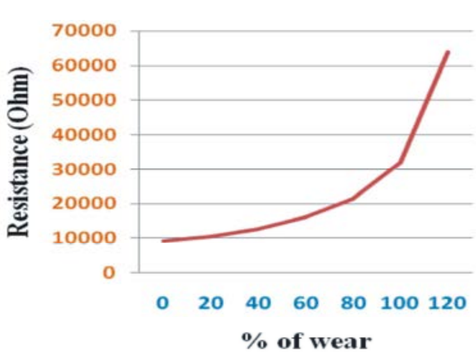

Fig. 7: Percentage of wear Vs Resistance

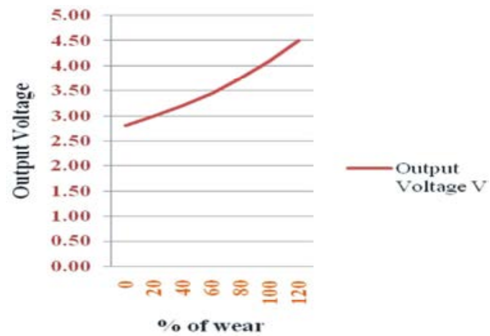

Fig. 8: Percentage of wear Vs Output voltage

Method of Indication: The sensed wear of the friction lining of the brake shoe must be conveyed to the driver of vehicle via driver information system to the dashboard of the vehicle [7]. The information provided to the driver must be simple and easy to understand. To keep the information to the driver as simple as possible LED bar graph is used [8]. To convert the voltage signal into LED bar graph a microcontroller is used.

CONCLUSION

For measuring the wear loss of the brake shoe of a vehicle, a continuous inspection method which employs series circuit is provided in this paper. The circuit diagram and measurement model of the senor are presented to perform the dynamic monitoring the abrasion loss for truck on the expressway. The scope of 1.0º-1.5º is derived for the optimal installation angle of the designed sensor as the asymmetry wear is caused by the kinematic relation of the brake shoe. Simulations among the on-circuit resistances of voltage divider, total resistances before and after a line worn out with the brake shoe are presented. The abrasion loss is tested by the output voltage related to the variation of resistance value on the circuit, for the practical applications, the accuracy will be enhanced by more resistances and subdivision of input voltage as well.

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