The Friction of Railway Brake Shoes Under Various Conditions of Pressure, Speed and Temperature.

By R. A. Smart.

Information concerning the friction of unlubricated rubbing surfaces is, unfortunately, limited in quantity, and it is believed that the data presented herewith, although relating particularly to the friction of brake shoes for railway cars, may be properly offered to the Academy as a contribution to the general subject.

The brake shoe is an important factor in the chain of mechanism popularly known as the air brake. It is not, strictly speaking, a part of the air brake, but is the immediate agent through which the air brake accomplishes the stopping of the train. It is the block of metal which is pressed against the tread of the car-wheel and which creates, in contact with the wheel, the friction which brings the wheel and hence the train to rest. It will at once be seen that the effectiveness of the whole air brake system on our railways is dependent directly upon the efficiency with which the brake shoe does its work. For instance, we can conceive of the brake shoe being made of some substance like glass, so hard that its friction would be practically nothing, in which case the air brake would be powerless to stop the train.

In fact, so important is the brake shoe in the eyes of railway officials that the Master Car Builders' Association has caused to be built an elaborate machine to be used exclusively for the testing of brake shoes. The need of such a machine will be understood when it is stated that the tendency of brake shoe manufacturers is, in order to be able to guarantee long life for their shoes, to make them so hard as to seriously impair their frictional qualities.

The Master Car Builders' Brake shoe testing machine, which has been deposited by them in the engineering laboratory of Purdue University, consists of a heavy revolving weight whose kinetic energy at any speed is equal to that of one-eighth of a loaded 60,000-pound freight car. On the same shaft as this weight and revolving with it is an ordinary car wheel. By a series of weighted levers, the shoe to be tested is pressed against the moving car wheel, thus bringing the wheel and, hence, the revolving weight to rest. When it is remembered that the freight car has eight wheels, each fitted with a brake shoe, it will be seen that the machine reproduces the conditions surrounding one-eighth of a freight car, so far as the forces involved in stopping the car are concerned. The machine provides a complicated recording mechanism by which the performance of the shoe while under test may be determined.

The present tests were undertaken to determine the effect upon the coefficient of friction of variations in three factors, viz.: The normal pressure between the shoe and the wheel, the speed of the wheel at the time the shoe is first applied, and the temperature of the rubbing surfaces. The effect of the first two variables was determined by making stops from various initial speeds and under different braking pressures, and calculating for each test the mean coefficient of friction for the stop. The limits of the variable elements under which the tests were made were as follows: Initial speed, 10 to 65 miles per hour; normal pressure, from about 2,800 pounds to about 10,700 pounds, these limits being the ones found in ordinary road service. In making a stop, the method of procedure is as follows: The weight and car wheel are brought to the desired speed of rotation by an engine. The engine is then disconnected from the revolving weight by a clutch and the brake shoe is brought in contact with the car wheel with the desired braking pressure. As the car wheel and weight are being brought to rest under the action of the brake shoe, the recording mechanism attached to the latter draws an autographic record of certain elements in the performance of the shoe, from which the mean coefficient of friction during the stop may be calculated.

The effect of the third variable mentioned above, namely, the temperature of the rubbing surfaces, was more difficult to determine. The temperature of the shoe only was observed, and this was found by imbedding in each end of the shoe the thermo-electric joint of a Le Chatelier pyrometer. This joint, in connection with a D'Arsonval galvonometer, gave continuous readings of the temperature of the face of the shoe near each end. The tests were made by making continuous runs at constant speed and noting simultaneously the temperature of the shoe and the coefficient of friction. The limits of temperature under which the tests were made were from about 60° F. to about 1500° F.

The results from the tests may be summed up as follows:

1. The coefficient of friction of brake shoes decreases with increase of pressure. The values are approximately as follows:

Soft cast-iron shoe.

Slow speed.

Pressure increasing from 2,700 pounds to 10,700 pounds.

Coefficient of friction decreasing from 37 per cent. to 20 per cent.

Soft cast-iron shoe.

High speed.

Pressure increasing from 2,700 pounds to 10,700 pounds.

Coefficient of friction decreasing from 25 per cent. to 15 per cent.

Hard cast-iron shoe.

Slow speed.

Pressure increasing from 2,700 pounds to 10,700 pounds.

Coefficient of friction decreasing from 33 per cent. to 18 per cent.

Hard cast-iron shoe.

High speed.

Pressure increasing from 2,700 pounds to 10,700 pounds.

Coefficient of friction decreasing from 17 per cent. to 12 per cent.

2. The coefficient of friction of brake shoes decreases with increase of initial speed. The values are approximately as follows:

Soft cast-iron shoe.

Light pressure.

Speed increasing from 10 to 65 miles per hour.

Coefficient of friction decreasing from 37 per cent. to 25 per cent.

Soft cast-iron shoe.

Heavy pressure.

Speed increasing from 10 to 65 miles per hour.

Coefficient of friction decreasing from 27 per cent. to 20 per cent.

Hard cast-iron shoe.

Light pressure.

Speed increasing from 10 to 65 miles per hour.

Coefficient of friction decreasing from 33 per cent. to 20 per cent.

Hard cast-iron shoe.

Heavy pressure.

Speed increasing from 10 to 65 miles per hour.

Coefficient of friction decreasing from 25 per cent. to 12 per cent.

3. The coefficient of friction of cast-iron brake shoes is practically constant with variations in temperature of shoe and wheel within the limits of the experiments.

Diamond Fluorescence.

[Abstract.]

By Arthur L. Foley.

A year ago I presented to the Academy an account of an experiment with a diamond and a photographic dry plate (Proceedings of Academy, 1899, p. 94). Later experiments have confirmed the theory presented. It has been found that a low temperature is favorable to the success of the experiment.

A Theorem in the Theory of Numbers.

By Jacob Westlund.

Let n be any prime number and let

$$S_k = 1^k + 2^k + 3^k + \dots\dots\dots\dots + (n - 1^{k}.$$

Then

$S_k \equiv 0$, mod n, when $k \not\equiv 0$, mod $(n-1)$ and $S_k \equiv -1$, mod n, when $k \equiv 0$, mod $(n-1)$.

Proof. Consider the congruence.

$$x^{n-1} - 1 \equiv (x-1)\ (x-2) \dots\dots\dots\dots (x - \overline{n-1}), \text{ mod } n.$$

This congruenee is evidently satisfied by the $n - 1$ incongruent numbers.

$$1, 2, 3, \dots\dots\dots\dots\dots\dots (n-1).$$