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A Study on the Friction Behavior of Natural Rubber

W. D. KIM, [1] D. J. KIM, [1] Changwoon Nah, [2] and Y. S. LEE [3]

[1] *Rubber Mechanics Lab., Korea Institute of Machinery and Materials*
171 Jang-Dong, Yusung-Ku, Daejeon, 305-343, KOREA
[2] *Dept. of Polymer Science and Technology, Chonbuk National University*
1Ga 664-14 Duckjin-Dong, Duckjin-Ku, Chonju, 561-756, KOREA
[3] *Dept. of Mechanical Design Engineering, Chungnam National University*
220 Gung-Dong, Yusung-Ku, Daejeon, 305-764, KOREA

The frictional characteristics of natural rubber plates under various conditions including sliding speed, contacted ball size, and lubrication conditions were evaluated experimentally. The frictional force and the normal force were measured by a self-made tester pin and a load cell with strain gages. In the lubrication condition, the effect of sliding speed was not significant over tested speed range. But in the none-lubrication condition, according to increase the sliding speed, the friction coefficient was decreased. The coefficients of friction under various lubrication conditions were varied from 0.03 to 0.32 and under none-lubrication condition was varied from 2.54 to 4.74

Keywords : Coefficient of Friction, Natural Rubber, Sliding Speed, Lubrication

1. INTRODUCTION

The mechanical system with rubber parts has been used widely in the many industry fields. The evaluation of the physical characteristic of rubber material is important in rubber application. Many engineers have studied to find the mechanical properties of rubber with various research methods. Some rubber components such as tire, o-ring and rubber belt were operated in conditions of friction and contact. The coefficient of friction is very important parameter to design and analysis of those rubber parts. In general, the coefficient of friction was obtained by the experimental method.

Cheon[1], Barquins[2] investigated the characteristics of friction for various temperatures and load range. Noriaki[3] studied the effects of the sliding speed and the contact pressure for various rubber shapes. Kim[4] dealt with the practical frictional problems of rubber experimentally for the effects of the sliding speeds, the lubrication conditions, the hardness of rubber plate, and the applied loads.

In this study, we designed and manufactured the friction tester. This tester consisted of the rotating table on which rubber plate was attached and the sensors to measure the frictional force and the normal force. It was investigated that the effects of the sliding speed, the lubrication condition, and the size of contacted ball on the coefficients of friction.

2. EXPERIMENT

2.1 Friction Tester

The friction tester was pin-on-disk type. This tester consisted of the rotating table on which rubber plate was attached and the sensors to measure the frictional force and the normal force.

The shape of rubber plates which was attached on the rotary table of tester is donut type. The normal force was measured by a self-made tester pin with strain gages. And the frictional force was measured by a self-made load cell which was the thin circular plate attached strain gages. The tester pin and the circular plate were deformed by external force, but these were deformed within the elastic range of materials.

The frictional force and the normal force were calculated by the measured strain values. Fig. 1 showed the schematic of sensors. The tester pin and the circular plate were located on the cantilever type measuring bar. Cantilever type measuring bar was fixed on the bed of friction tester. The normal force was applied by the dead weight block. The amplitude of the force was controlled by the weight of block and the position of weight block.

2.2 Test Condition and Test Procedure

To evaluate and analyze the coefficient of friction various test conditions were applied, which were the sliding speed, the lubrication condition, and the size of ball. The normal force of 5 N was applied. The sliding speeds were 25 mm/s, 50 mm/s, 75 mm/s and 100 mm/s.

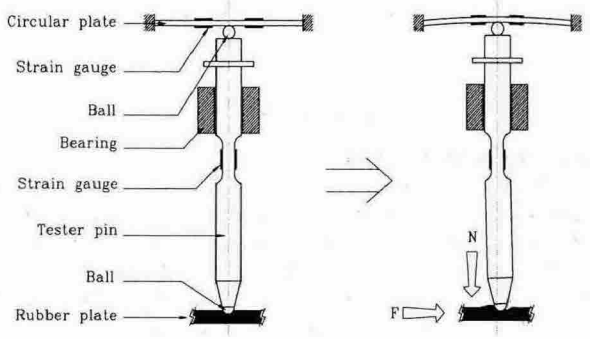

Fig. 1 Schematic diagram of sensors to measure the frictional force and the normal force

Table 1 Test conditions

Conditions	Variations
Sliding Speed (mm/s)	25, 50, 75, 100
Normal Force (N)	5
The Diameter of Ball (mm)	8, 12
Hardness (IRHD A)	55
Thickness of Rubber Plate (mm)	4
Lubrication	None, Water, Soapy Water, Oil

Water, soapy water and lube oil were used as lubricants between the rubber plate and the steel ball. Also, none-lubrication condition was tested. A steel ball was fixed on the tip of tester pin. The diameter of ball is 12 mm and 8 mm. Table 1 shows various test conditions. There are 3 steps in the test procedure. The first step is an acceleration step which is from 0 to 60 seconds. The second step is a stabilizing speed range which is from 60 to 90seconds. In the third step after about 90 seconds the coefficient of friction is measured.

2.3 Measurement of the coefficient of friction

The measured signals from the sensors are processed in the data acquisition system and the coefficient of friction μ is calculated by next equation.

$$\mu = F / N \qquad (1)$$

Where, F is the friction force which is generated by bending strain of the tester pin, and N is the normal force which is generated by bending strain of the circular plate.

3. RESULT AND DISCUSSION

3.1 Effect of lubrication conditions

The various lubrication conditions which were water, soapy water, and oil, were investigated. Also, none-lubrication was tested. Oil is DTE-25 which was manufactured by Mobil Company. In none-lubrication condition, the coefficient of friction was distributed from 2.54 to 4.74. In oil lubrication, it was distributed from 0.03 to 0.07. The coefficient of friction in soapy water was distributed from 0.11 to 0.22. In water it was distributed from 0.14 to 0.32. Fig. 2 shows the range of the coefficients of friction for various lubrication conditions.

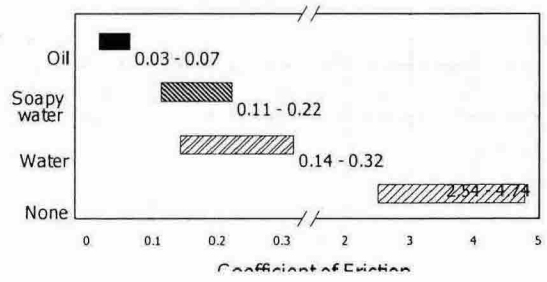

Fig. 2 Effect of lubrication conditions on the coefficient of friction

3.2 Effect of Ball Size

The effect of the ball size on the coefficient of friction was investigated. The diameters of balls were 12 mm and 8 mm. According to the ball size, the contact pressure between the rubber plate and the ball was changed. In none-lubrication, the coefficient of friction with 12 mm was distributed from 2.54 to 4.15. With 8 mm, it was distributed from 2.64 to 4.74. In oil lubrication, it was distributed from 0.035 to 0.056 with 12 mm, and it was distributed from 0.053 to 0.07 with 8 mm. In soapy water, it was ranged from 0.117 to 0.191 with 12 mm, and it was ranged from 0.156 to 0.226 with 8 mm. In water, it was ranged from 0.137 to 0.315 with 12 mm, and it was ranged from 0.173 to 0.314 with 8 mm. Fig. 3 shows the range of the coefficient of friction for ball sizes of 12 mm and 8mm.

3.3 Effect of Sliding Speed

The effect of the sliding speed on the coefficient of friction was investigated. The range of the sliding speed was from 25 to 100 mm/s. The coefficients of friction in various lubrication conditions were constant, but in none-lubrication condition it was decreased according to increasing sliding speed. Fig. 4 shows the coefficients of friction for various sliding speeds.

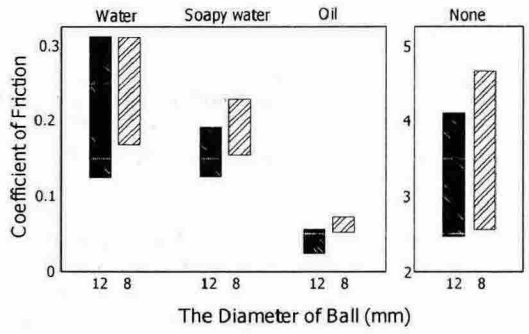

Fig. 3 Effect of ball size on the coefficient of friction

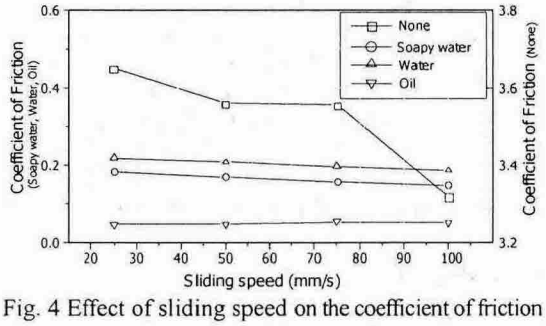

Fig. 4 Effect of sliding speed on the coefficient of friction

4. CONCLUSIONS

The frictional characteristics between the rubber plate and the steel ball were investigated by experimental method. In none-lubrication condition, the coefficient of friction was very high over 2.0. And in oil lubrication condition, it was below 0.1. It was found that the frictional characteristics were greatly depended on the lubrication conditions.

In the evaluation of the effect of ball size, it was shown that the coefficient of friction of steel ball with 8 mm was slightly larger than steel ball with 12 mm ball. And there were some difference depending on lubrication conditions.

The coefficient of friction for the sliding speed of from 25 to 100 mm/s was measured. In lubrication condition, the friction coefficient is constant. But in none-lubrication, the frictional coefficient decreases with the increase in sliding speed.

5. REFERENCES

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