EXPERIMENTAL MEASUREMENTS OF FRICTION BETWEEN SPONGE RUBBER AND STEEL

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ABSTRACT: The coefficient of friction is important property of materials. Sponge rubber was used as a sample in the test. Sponge rubber used in coulombian damper (generally the rubber has viscoelastic properties). The dynamic friction between sponge rubber and steel ball can be found. In this study, the test used to measure the coefficient of friction between steel ball and sponge rubber as a function of angular velocity and different pressure. The results showed that the coefficient of dynamic friction decreased when the contact pressure increased, whereas it's increased when the angular velocity increased. Experimental results are investigated by using load cell sensor.

KEY WORDS: Rubber, Coefficient of friction, Angular velocity, Sensor, Four ball machine

1. INTRODUCTION

Rubber friction is a topic of large practical importance in applications, such as tires, rubber seals, syringes and conveyor belts. In recent studies the rubber uses for damping because viscoelastic properties that is appeared in coulombian damper (shock absorbers). Damping phenomena based on friction between rubber and another material to reduce the vibration in the systems. However, there is an imperfect comprehension of the some parameters that control the friction conduct of rubber surfaces. Since the seminal experimental work by Grosh [1], frictional mechanisms including losses of viscoelastic at micro-asperity scale have induce the development of different theoretical models beginning from Fourier transform analysis used to periodic surfaces [2,3] to the complex model developed and expanded by Persson for viscoelastic material (rubber) friction on rough surfaces [4,5]. Utilizing a spectral description of the rough surfaces, Persson's research predicts how the friction force component connected with hysteretic losses differs with contact pressure and angular velocity from an estimate of the real contact area. Some experimental outcome supports his theory [6]. Den Hartog and Ormondroyd used energy approach to prove that the optimum friction torque is proportional to the torque acting on the primary system [7]. Miguel Trejo al el. They show the friction of viscoelastic material (rubber) with rough surfaces under conditions of the torsional contact.

2. EXPERIMENTAL STEP UP

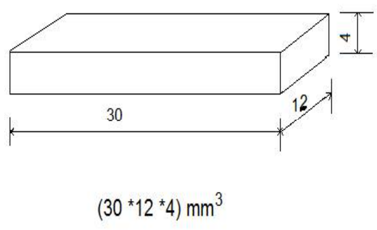
In this part of the study we are used the following to investigate the goal
1- Rubber sample with dimensions (l *w * t) mm is used for the experimental as shown in Figure 1 where: b is the wide of the sample (12 mm), l is the length of the sample (30 mm) and t is the thickness of sample (4 mm).

2- TAL201 load cell (maximum measuring range 100 Newton), a steel ball tip with diameter 12.75 mm,
3- Amplifier- HX711 and Arduino maga-2560 are used. Amplifier- HX711 used to convert the analog signal to digital signal
4- Arduino maga-2560 used to transport the digital signal to the personal computer.
5- Steel ball tip as shown in figure 2 a

All these devices have been installed on machine four balls to measure the dynamic friction coefficient between rubber and steel ball as shown in Figure 3; this test was developed by the Haider, Andrei and Kussay. Normal loads for different velocities are applied as shown in table.1. the rubber sample has dimensions

Table 1. Normal load and angular velocities

Normal load(N)	ω1 rad/s	ω2 rad/s	ω3 rad/s	ω4 rad/s
2.5	2.1	6.23	8.37	12.47
5	2.1	6.23	8.37	12.47
7.5	2.1	6.23	8.37	12.47
10	2.1	6.23	8.37	12.47

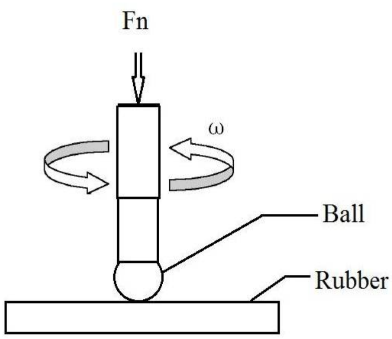


(a)

(b)

Figure 1. A sample of rubber and geometry shape

(a)



(b)

Figure 2. Iron steel ball tip (a) and Steel ball contact with rubber (b)

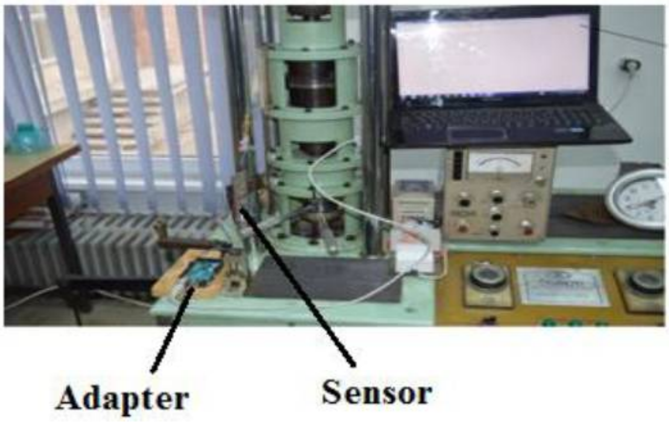


Figure 3. Adapting device used to measure the kinetic friction

3. RESULT AND DISCUSSIONS

The results are related to investigation of the important mechanical properties of rubber such as friction coefficient as a function of parameters including angular velocity, normal load.

3.1. Tangential Force

The sensor reading tangential force by using Arduino software and save the results in computer connected to system as shown in Fig.3. We note the tangential force increases when angular velocity and normal load are increases as shown in figure 4. It clears the maximum tangential forces (F_t) at angular velocity 12.47rad/s: are

F_t= 0.17N at normal load 2.5N
F_t= 0.209N at normal load 5N
F_t= 0.264N at normal load 7.5N and
F_t= 0.315N at normal load 10N.

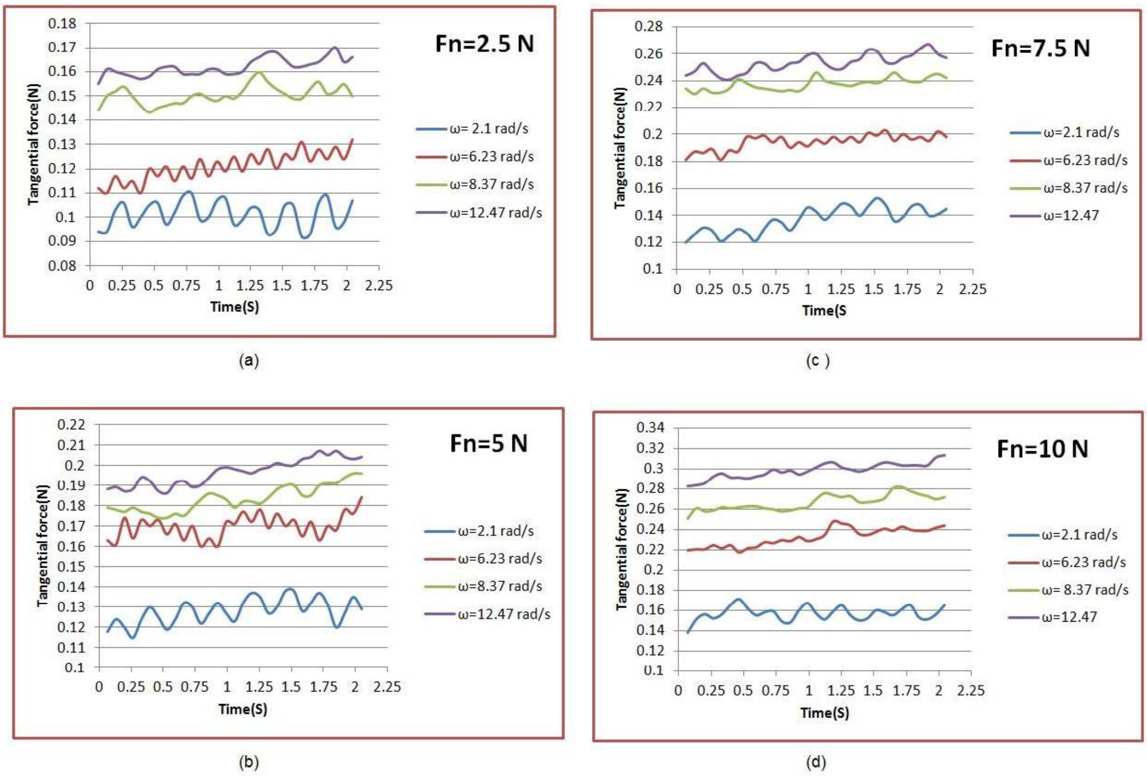


Figure 4. Tangential force for different load and angular velocities

3.2. Coefficient of Dynamic Friction

Coefficient of dynamic friction can be calculated from the following relations where F_t is the tangential force, F_n is the normal load.

M_b is the moment of the ball (N.mm)

$$M_b = k * F_n * r_b \quad (1)$$

M_t is the genrated moment from tangential force (N.mm)

$$M_t = F_t * x \quad (2)$$

Where r_b is the raduis of ball, x is the distance from center of the tip to the sensor. The values are: r_b=6.375 mm; x= 185 mm and k =10.

The friction coefficient will be

$$\mu = M_t/M_b \; ; \; \mu = 2.9F_t/F_n \quad (3)$$

The friction force is

$$F_f = \mu . F_n \quad (4)$$

Fig. 5 shows the dynamic coefficient of friction (μ) as a function of angular velocity(ω) at different loads (2.5N, 5N, 7.5N and 10 N). Generally, the coefficient of dynamic friction is very important mechanical property of metal. figure 5 shows the coefficient of friction increases when the angular velocity increases.

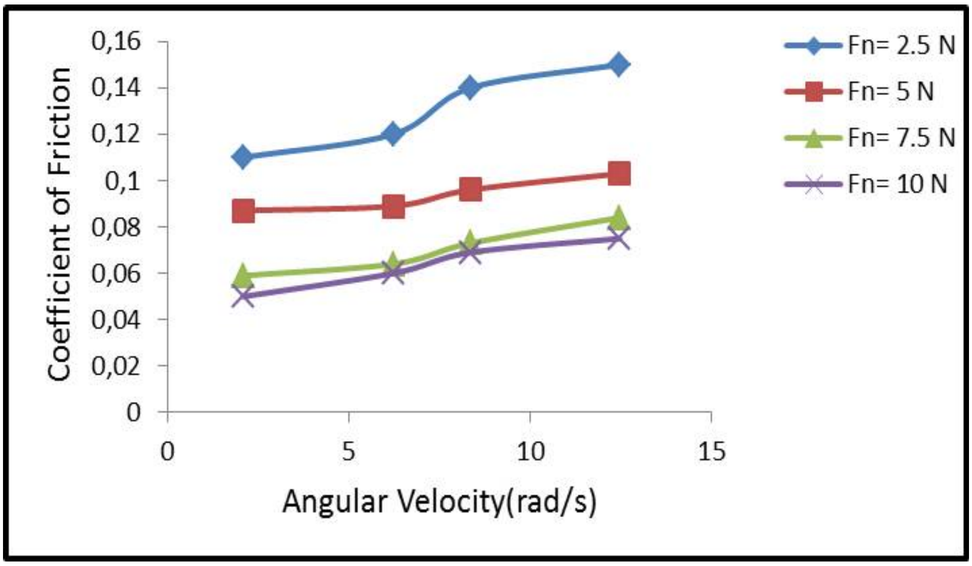


Figure 5. The coefficient of friction vs. angular velocity

Figure .6 shows the coefficient of dynamic friction as a function of applied pressure on the sponge rubber at different angular velocities (v_1=2.1rad/s, v_2=6.23rad/s, v_3=8.37rad/s and v_4=12.47 rad/s) that mean as shown in figure 6 the coefficient of friction decreases when the conventional pressure increases at all angular velocities.

When the normal load on rubber increases the pressure increases that leads to decrease in coefficient of dynamic friction.

Note : (the convential presure is $P=F_n/A_b$, where A_b is the area of ball, $A_b = r^2 * \pi$, r is

Figure 7 shows the relationship between dynamic friction force and normal force the friction force increases when normal load increases.

The coefficient of friction is higher at a pressure of 19.6 kPa and speed of 12.47 rad/sec than in the other operating conditions, therefore increasing in the normal force on the rubber leads to increase in coefficient of friction.

the radius of the ball).

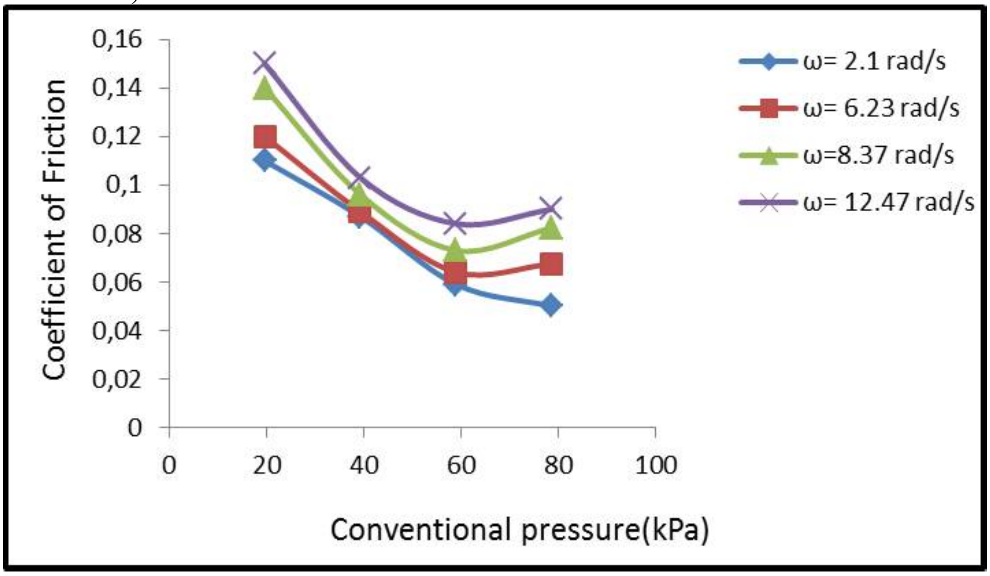


Figure 6. The coefficient of friction vs.conventional pressure.

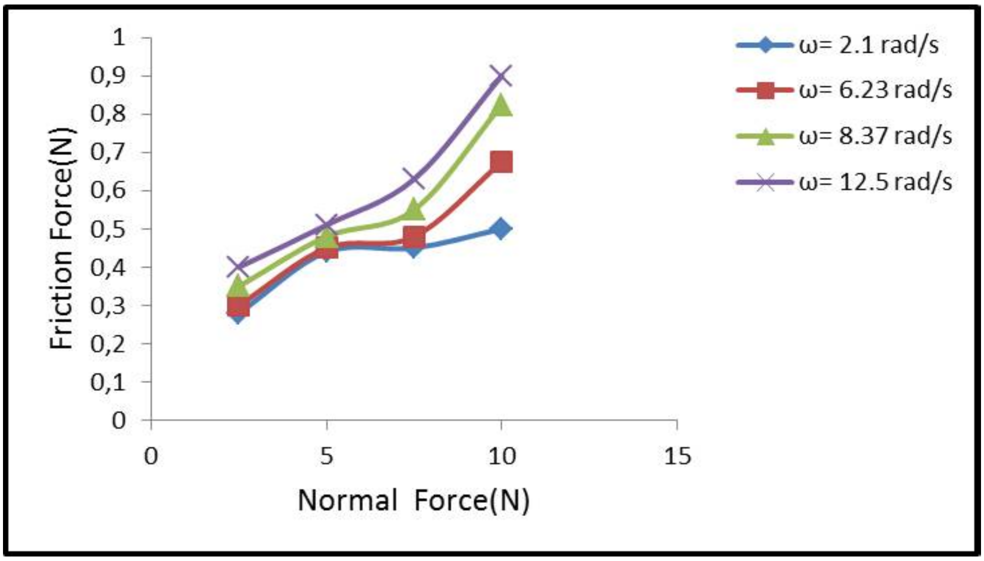


Figure 7. friction force vs. normal force

4. CONCLUSIONS

The coefficient of friction for rubber was measured at different pressures and different angular velocities. The rubber has mechanical properties such as viscoelastic and non-linear. Based on the obtained results, the following conclusions:

The coefficient of dynamic friction increased when the angular velocity increased in the range (2.1-12.47 rad/s) and the coefficient of dynamic friction decreased when the pressure increased (20 -80 kPa).

5. REFERENCES

[1] Grosch, A. K. The relation between the friction and visco-elastic properties of rubber, Math. Phys. Sci. **Vol** 274, 21, (1963)

[2] Schapery, R. A. Analytical Models for the Deformation and Adhesion Components of Rubber Friction, Tire Science and Technology: February **Vol** 6, No. 1, pp. 3-47(1978)

[3] Golden, J. M. Hysteresis and lubricated rubber friction, Wear 65, Pages 75-87, **Vol** 75 (1980)
[4] Persson, B. N. J. Contact mechanics for randomly rough surfaces, Sci. Rep. **Vol** 61, 201(2006)
[5] Person, B. N. J, Theory of rubber friction and contact mechanics, jounal of chemical physics **Vol**115, 2840 (2001)
[6] Lorenz, B. Persson, B. N. J. Dieluweit, S. and Tada, T. Rubber friction: Comparison of theory with experiment, The European Physical Journal E, **Vol** 34, 129 (2011).
[7] Miguel Trejo, Christian Fretigny, and Antoine Chateauminois, Friction of viscoelastic elastomers with rough surfaces under torsional contact conditions, Physical Review E Persson **Vol** 88, 052401 (2013)