DEVICE FOR STUDYING SLIDING FRICTION

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Abstract: *An experimental device was designed and developed to study the friction coefficient between a steel bar and two drive rollers on which it is supported. Movement of the steel bar is achieved by means of two rods mounted on bearing and driven by two engines. The two rollers have rotational movements with equal and opposite as sign angular velocities. These cause a harmonic motion of the horizontal bar. By measuring the oscillation period of the steel bar, the friction coefficient between the bar and the drive roller is obtained.*

Keywords: *bearing, friction, drive roller.*

1. Introduction

The dry friction laws have been developed over a long period of time and with the contribution of many philosophers and scientists, because describing the friction phenomenon is not a simple task.

Aristotle (384-322 BC) was the first to observe in his "Questiones Mechanicae", that the friction force is smaller in the case of round objects, Dowson [1].

Leonardo da Vinci (1452-1519) introduces the concept of coefficient of friction and assigning the value of 0.25. His manuscripts were unknown for a long time, being published only at the end of the 9th century in the Codex Atlanticus.

The friction experiments of Guillaume Amontons (1663-1705) were presented at the Royal Academy in December 1699.

In 1750, mathematician Leonhard Euler (1707-1783) distinguishes between static and kinetic friction and concludes that static friction is biger than kinetic friction, Bowden and Tabor [2]. He introduces the symbol "μ" for the friction coefficient and develops the equation $\mu = tg\alpha$.

The wellknown law of friction $\mu = T / N$, bears the name of French engineer Charles Augustin Coulomb (1736-1806). He investigated both friction in bending of ropes and in rolling, Coulomb [3].

2. Theoretical model

A heavy uniform bar of mass M rests on top of two identical rollers of radius r, the distance between the centres of the rollers being 2d. Initially, the bar is held at rest with its centre at distance x from the midpoint of the rollers. At the time t=0 it is released on the rollers that are continuously turned rapidly in opposite directions, as shown in Figure 1. It is intended to find the law of the bar movement, assuming μ as roller - bar friction coefficient

The isolated bar is acted on by normal forces N_1 and N_2 in contact points C_1 and C_2. At the same points act the friction forces T_1 and T_2. The bar weight is $G = Mg$.

The equations of motion on the two axes are:

$$\text{ox:}\quad N_1 + N_2 - G = 0 \qquad (1)$$

$$\text{oy:}\quad T_1 - T_2 = M \cdot \ddot{x} \qquad (2)$$

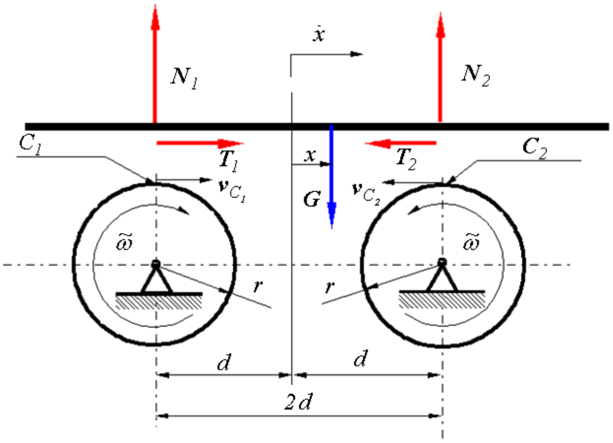

Figure 1. Free body diagram

The sum of the moments of the forces of any point is zero, including the mass centre of the bar.

$$-N_1(d+x) + N_2(d-x) = 0 \qquad (3)$$

From equations (1) and (3) it follows:

$$N_1 = \frac{Mg}{2}\left(1 - \frac{x}{d}\right)$$

$$N_2 = \frac{Mg}{2}\left(1 + \frac{x}{d}\right)$$

$$T_1 - T_2 = \mu(N_1 - N_2) = -\frac{\mu \cdot M \cdot g}{d} x$$

So equation (2) becomes:

$$M \cdot \ddot{x} = -\frac{\mu \cdot M \cdot g}{d}$$

$$\ddot{x} + \frac{\mu \cdot g}{d} x = 0$$

$$\ddot{x} + \omega^2 \cdot x = 0$$

$$x = x_0 \cdot \cos \omega t$$

A harmonic motion equation was obtained, with pulsation: $\omega = \sqrt{\frac{\mu g}{d}}$

It results from the calculus that the bar performs in these conditions a harmonic oscillatory motion with pulsation ω

3. Experimental device

In order to validate the theoretical model presented above, the device from Figure 2 was built.

The device consists of two parallel rods placed on a support plank. At one end of the rods there are the two engines, and at the other end there are two sets of drive rollers, which support the bar whose motion is studied.

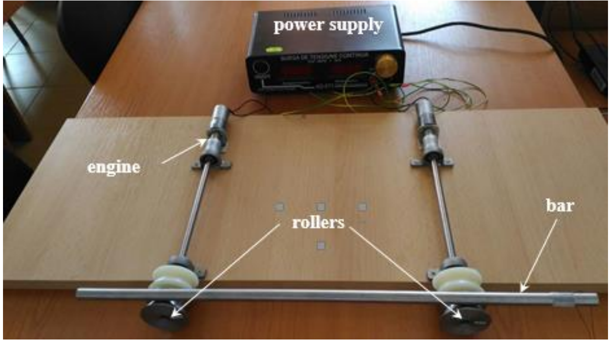

Figure 2. Experimental device

The drive rollers of different materials are shown in Figure 3.

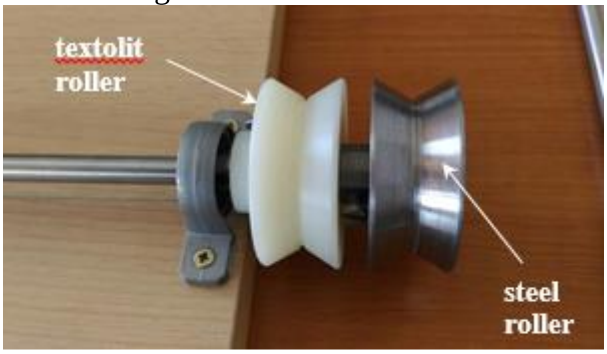

Figure 3. Rollers

A set of rollers is made of steel and a set is made of textolite. Thus, the experiments can be done with different pair of materials. On the outside, the rollers practiced a V-shaped groove to allow the cylindrical bar to be correctly supported. Support horizontal axis on which are mounted rollers is made with a necklace bearing.

At the opposite end, the engine is trapped in a reducing sleeve that connects the horizontal rod, locks being kept by a clamp bearing.

Before starting the experiment, the device was held horizontally by means of electronic buckling to ensure that the friction forces on the two rollers are perfectly horizontal and correspond to the theoretical modeling.

The engines are operated by a continuous voltage source,-fixed at maximum 6 volts. The binding of the two engines was made in such a way that their rotation is equal and opposite.

The engine speed was measured using a digital tachometer, Figure 6, using a phosphorescent band attached on the front of the steel roller. A rotation of 123.9 rpm was obtained at a speed corresponding to the engine data sheet.

Figure 4. Drive system

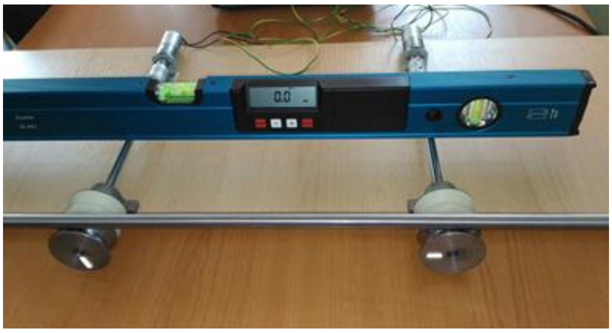

Figure 5. Horizontality check

The engines are operated by a continuous voltage source,-fixed at maximum 6 volts. The binding of the two engines was made in such a way that their rotation is equal and opposite.

The engine speed was measured using a digital tachometer, Figure 6, using a phosphorescent band attached on the front of the steel roller. A rotation of 123.9 rpm was obtained at a speed corresponding to the engine data sheet.

Figure 6. – Measurement the engine speed

4. Preliminary experimental results

4.1 Determination of the coefficient of friction using the harmonic oscillation of the bar

According to the theoretical model, the pulsation of rod harmonic oscillatory motion will be

$$\omega = \sqrt{\frac{\mu g}{d}}$$

where:

μ is the unknown friction coefficient,

g is the gravitational acceleration, $g=9.81$ m/s^2

d is half distance between the two rollers axis.

The oscillation period of the rod was measured by means of video filming, as time divided by number of complete oscillations:

$$T = \frac{t}{n}$$

Obtained period is: T=1.9 s

Knowing that:

$$\omega = \frac{2\cdot\pi}{T} \quad \rightarrow \quad \frac{2\cdot\pi}{T} = \sqrt{\frac{\mu g}{d}}$$

The friction coefficient is:

$$\mu = \frac{4\cdot\pi^2\cdot d}{T^2\cdot g}$$

The half distance between the roller axis is d=0.15m.

The obtained friction coefficient between the steel roller and the bar, which is

$$\mu = 0.17$$

ACKNOWLEDGEMENT

This work was partially supported from the project “Integrated Center for research, development and innovation in Advanced Materials, Nanotechnologies, and Distributed Systems for fabrication and control”, Contract No. 671/09.04.2015, Sectorial Operational Program for Increase of the Economic Competitiveness co-funded from the European Regional Development Fund.

Conclusion

The paper presents a device for evaluating the friction coefficient between a bar and a roller. By imposing a rotational motion with equal angular and opposite angular velocities, particular kinematic conditions are obtained that cause a harmonic oscillatory movement of the bar.

By measuring the oscillation period and using the relations deduced from the theoretical modeling, the friction coefficients bar-roller is calculated. The values obtained in the two conditions have a relative error of only 3%, and values are in good agreement with literature data for steel-steel coefficient of friction, [4], ($\mu = 0.16\text{-}0.3$)

References

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