FRICTION OSCILLATOR

Sahar Semsarha ,Farzanegan2 high school, Tehran/ Iran, sahar.sems@gmail.com

ARTICLE INFO

Winner of Silver Medal , IMSEF 2020, Turkey

Participated in O-IYPT 2020

Accepted in country selection by Ariaian Young Innovative Minds Institute , AYIMI

http://www.ayimi.org ,info@ayimi.org

ABSTRACT

This essay is about oscillation of a massive object place on the rotating cylinders' witch rotate in opposite directions. The place and frequency of the massive object have been investigated. Although a simulation has been presented and affective parameters like friction coefficient, distance between cylinders have been investigated.

Key Words *:oscillation, frequency, rotating cylinders, simulation*

1 Introduction

This experiment is about the motion of a massive object placed into two identical parallel horizontal cylinders which rotate with the same angular velocity, but in opposite directions. When the cylinders start to rotate, the massive object will oscillate horizontally. Kinetic friction, friction coefficient and frequency of the rod have been investigated (Robin Hena and Et al.) also energy based solution and the turning and stopping points have been presented by Avi Marchewkaa and Et al. but they emphasized on the amplitude of the oscillator damping by a constant magnitude. In this study other different parameters are investigated too.

2 Experimental Setup

An aluminum rod is used as a massive object and two-car pulleys (with 8cm diameter) placed on two rods . A Van de Graaff generator belt is used to connect the cylinders. The belt was applied crossed over the cylinders to provide the opposite direction movement. Van de Graaff generator belt has low elasticity and friction doesn't make it warm so it can decrease errors. Three holes are used to change the place of the second cylinder as parameter. A sewing motor is used to change the speed of the cylinder. I've used speed controlling device to control the speed. Whenever It was pulled, speed is increased (Figs. 1 and 2).

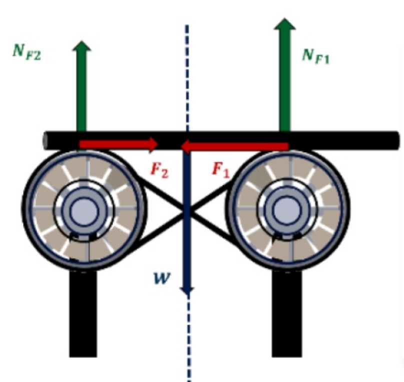

Fig. 1: Friction Oscillator Moddeling

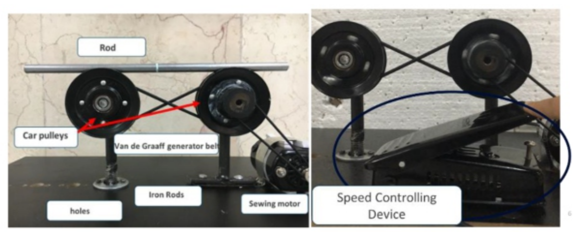

Fig.2: Experimental Setup

3 Theory

3-1 Amplitude of the Oscillation

There are three forces affecting the rod ; Normal force, friction, and weight. When the rod starts to move the weight applied on one of the cylinders will be more than the other one so it makes one of the normal forces to be greater. As a result, the friction in one point will be greater than the friction in other part so the rod will move toward opposite direction and this frequent occurrence makes the oscillation.

When the rod is placed exactly in the middle, it makes the frictions to be equal to each other so the rod will remain standing on its place. But in experimental result this will rarely happen so we can consider that the rod will always start to move. In order to investigate this phenomenon theoretically the friction must be calculated.

According to the Newton's second law the forces can be written (Eq. 1).

$$mg = N_1 + N_2 \tag{1}$$

and according to the torque , the normal force in each side is given by equations (2-4):

$$N_1\left(\frac{d}{2} - x\right) = N_2\left(\frac{d}{2} + x\right) \tag{2}$$

then:

$$N_1 = mg\frac{d + 2x}{2d} \tag{3}$$

$$N_2 = mg\frac{d - 2x}{2d} \tag{4}$$

By these normal forces, frictions can be calculated as well

(Eq. 5).

$$F = -\mu_1 N_1 + N_2\mu_2 = \frac{mg}{2d}(-\mu_1 d - \mu_1 2x + \mu_2 d - \mu_2 2x) \quad (5)$$

The place of the rod can be calculated by equation (6) which X_0 is the place that summation of the forces affecting the rod is zero. It is the place that frictions are equal to each other. X_0 Will be in the middle of the cylinders where the friction coefficient of the cylinders are the same. δ is distance of the rod from X_0 . Second derivation of X_0 is equal to the second derivation of δ because X_0 is constant (Eq. 7).

$$x = x_0 + \delta \quad (6)$$

$$\ddot{x} = \ddot{x_0} + \ddot{\delta} = \ddot{\delta} \quad (7)$$

Then:

$$F = m\ddot{x} = m\ddot{\delta} \quad (8)$$

$$\ddot{\delta} = \frac{g}{2d}\left((\mu_2 - \mu_1)d - (\mu_1 + \mu_2)2x_0 - 2\delta(\mu_1 + \mu_2)\right) \quad (9)$$

$$x_0 = \frac{d}{2}\frac{\mu_2 - \mu_1}{\mu_1 + \mu_2} \quad (10)$$

$$\ddot{\delta} = -\frac{g}{d}\delta(\mu_1 + \mu_2) \quad (11)$$

By solving the differential equation the place of the rod can be achieved in each second (Eqs. 12-15).

$$\delta = A\cos\omega t + B\sin\omega t \quad (12)$$

$$x = x_0 + A\cos\omega t + B\sin\omega t \quad (13)$$

$$A = x - x_0 \qquad B = \frac{V_0}{\omega} \quad (14)$$

$$x = x_0 + \left((x - x_0)^2 + \frac{V_{(0)}^2}{4\pi^2 f^2} \right)^{\frac{1}{2}} \cos(\omega t + \varphi_0) \quad (15)$$

In our experiments friction coefficient of the cylinders are the same. Xo have been considered 0 in both experimental and theoretical results. No velocity have been given to the rod in first situation in order to omit the V_0. By omitting V_0 φ_0 will be crossed out as well. So it shows that wherever the rod is placed in the first situation X_0 will be the amplitude of the oscillation.

3-2 Frequency of the Oscillation

ω and frequency are calculated as equations (16 and 17) :

$$\omega = \sqrt{\frac{g(\mu_1+\mu_2)}{d}} \quad (16)$$

$$f = \frac{\sqrt{\frac{2g\mu}{d}}}{2\pi} = \frac{1}{\pi}\sqrt{\frac{g\mu}{2d}} \quad (17)$$

According to the frequency formula, only friction coefficient and distance between two cylinders can affect this phenomenon. As much as distance between cylinders increases the frequency will decrease and as much as friction coefficient increases the frequency increases too.

4 Experimental Procedures

Different parameters are investigated in this experiment. Length of the rod, angular velocity of the cylinder and mass of the rod have no important role and don't affect the frequency as it is shown in Figures (3-5).

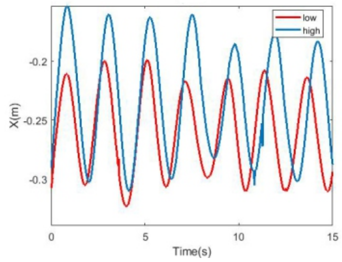

Fig. 3: Place of the rod versus Time in two different angular Velocities of the cylinders (low and high)

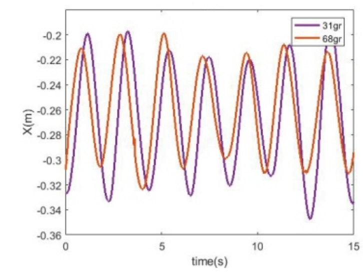

Fig. 4: Place of the rod versus Time in two different masses of the rod (31 and 68 gr)

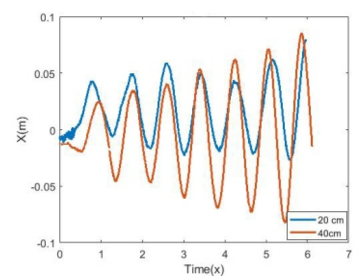

Fig. 5: Place of the rod versus Time in two different lengths of the rod (20 and 25 cm)

According to the equation (17) three affective parameters have been considered. These parameters are distance between two cylinders, friction coefficient between the rod and the cylinder, and the slope between the set up and the ground .

It is shown as much as friction coefficient between the rod and the cylinder increases the frequency will increase too (Fig. 6).

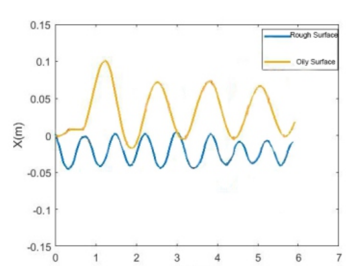

Fig. 6: Place of the rod versus Time in two different surfaces (oily and rough)

According to experimental data and equation (17), as much as distance between cylinders increases frequency will decrease (Fig. 7).

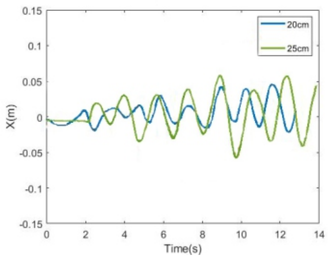

Fig. 7: Place of the rod versus Time in two different distances between cylinders

5 Simulation

The theoretical and experimental results of this phenomenon have been simulated by Matlab. The amplitude of the oscillation is an input in the simulation and the frequency is calculated from equation (17).

The outputs of the simulation gives the place of the rod in each second and a chart that compare the frequency and amplitude in experimental and theoretical results (Fig. 8).

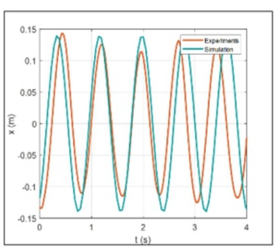

Fig. 8: Place of the rod versus Time , Comparison between simulation and experiment

It has been considered that the amplitude is constant and equal to the initial distance from X_0 but duo to the errors it is not always constant and might change . In ideal system the Normal forces must just affect the rod from the below but in experimental setup the Normal force on the rod is applied on the corners as well and that can cause some errors (Fig. 9).

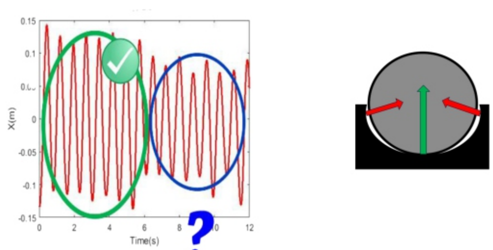

Fig. 9: Fluctuations in amplitude due to the errors in experiments

To decrease these errors, motor was used so the speed of the cylinders increased a lot and both the rod and cylinders didn't move with each other. That caused a usability in the movement of the rod which change the amplitude of the oscillation.

6 Conclusion

By investigating the forces which are applied on the rod, a differential equation has been achieved which shows frequency and amplitude of the oscillation.

According to experimental data and equation (17), frequency will decrease by increasing the distance between cylinders and increases by increasing the friction coefficient between the rod and the cylinder (Figs. 10 and 11).

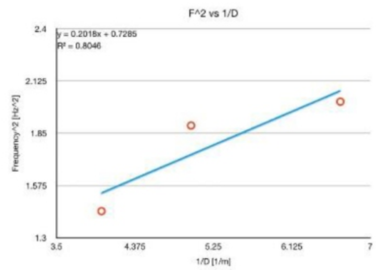

Fig 10. Frequency by changing the distance between two cylinders (Theory vs Experiment)

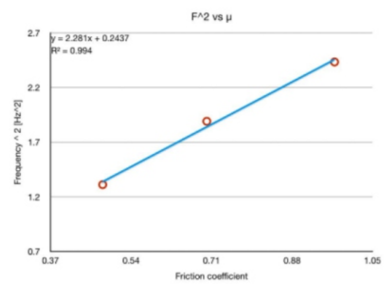

Fig 11. Frequency by changing the friction coefficient (Theory vs Experiment)

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