HANGING ELEVATOR

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ABSTRACT

Hanging Elevator is a system which stop the elevator from falling and crashing. The main purpose of this project is to find a way to stop elevator from falling. The cable of elevator that hold the elevator may rupture; if it ruptures , the elevator will fall down and crash and causes damages. Hanging Elevator is basically related to the phenomenon that we called it "Looping Pendulum". In this research we are going to investigate the parameters which affect this experiment and what relations between this parameters cause a better result in an ideal system.

1 Introduction

The Hanging Elevator is a system which stops the elevator from falling and crashing which is basically related to the phenomenon that we called it 'Looping Pendulum' [1]. Based on Looping Pendulum, when we connect two loads, one heavy and one light, with a string over a horizontal rod and lift up the heavy load by pulling down the light one and by releasing the light load and it will sweep around the rod, keeping the heavy load from falling to the ground [2]. To find an ideal system , several experiments are done and the parameters which affect these experiments are investigated.

2 Methods and Modeling

For Hanging Elevator, we designed a structure as our main system that gives us the least errors . There are 3 steps for this structure. First, we put bar with 10 mm radius on the flat surface; then for measuring the angle of extrication, we design a protractor and locate it in front of the axis. Third for connecting the weight and wooden elevator (maquette), we use a woolen string. Finally for weight, we use metal weights with specific masses (Fig. 1).

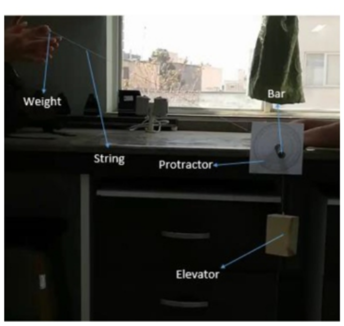


Fig. 1: : Experimental Setup

3 Theoretical Analysis

A light load (m_1) is connected to a heavy load (m_2) with a string that its length is L. The system is over a horizontal rod of radius r .As you can see in Figure (1), a coordinate system is attached to the origin of the rod while its *x* axis is in the horizon direction. The length of the string is decomposed in three parts; *s* is the distance from light object to the first contact point of string with rod, *l* is the length of string in contact with rod, *H* is the distance from heavy load to the contact point with rod and assuming rigid string, the equations are written(Eq. 1-8)(Fig. 2).

$$L=s+l+H \qquad l=r\,\phi \qquad \phi=\frac{\pi}{2}+\theta \tag{1}$$

$$\vec{R}_1 = r\,\hat{r}+s\,\hat{\theta} \tag{2}$$

$$\vec{V_1} = \dot{\vec{R}}_1=(r\dot{\theta}+\dot{s})\hat{\theta} - s\,\dot{\theta}\,\hat{r} \tag{3}$$

$$\vec{a}_1 = \ddot{\vec{R}}_1 = (r\ddot{\theta}+\ddot{s} - s\dot{\theta}^2)\hat{\theta} - (r\dot{\theta}^2 + s\ddot{\theta} + 2\dot{s}\dot{\theta})\hat{r} \tag{4}$$

$$W_2 \sin\theta - T_2 = m_2(r\ddot{\theta} + \ddot{s} - s\dot{\theta}^2) \tag{5}$$

$$W_2 \cos\theta = m_2(r\dot{\theta}^2 + s\ddot{\theta} + 2\dot{s}\dot{\theta}) \tag{6}$$

$$W_1 - T_1 = m_1\ddot{H} \Longrightarrow W_1 - T_1 = -m_1(\ddot{s} + r\ddot{\theta}) \tag{7}$$

$$T_1 = T_2 e^{\mu\varphi} \tag{8}$$

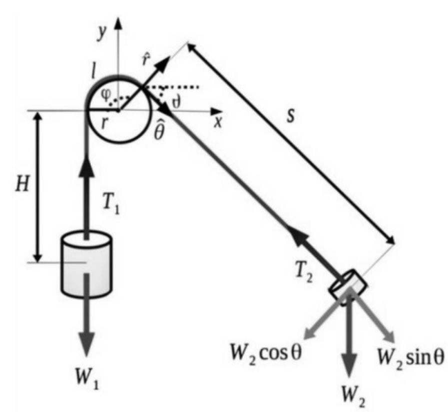


Fig. 2: Free body diagram

According to free body diagram and equations, there are 4 forces acting on the light mass (m_1) that contain Gravitation force [3], Centripetal force [4], Tension force [5] and Coriolis force [6] as following equations (Eq. 9-12) (Fig.3).

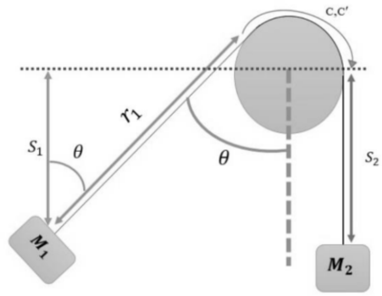


Fig. 3: Free body diagram of forces acting on masses

$$\left.\begin{aligned} l &= c + r_1 + r_2 \\ 0 &= 0 + \dot{r}_1 + \dot{r}_2 \\ 0 &= \ddot{r}_1 + \ddot{r}_2 \end{aligned}\right\} 1 \tag{9}$$

$$\left.\begin{aligned} l &= C' + S_1 + S_2 = C' + r_1\cos\theta + S_2 \\ 0 &= 0 + \frac{d(r_1\cos\theta)}{dt} + \dot{S}_2 \end{aligned}\right\} 2 \tag{10}$$

$$\left.\frac{d(r_1\cos\theta)}{dt} = \dot{r}_1\cos\theta - r_1\dot{\theta}\sin\theta = \right\} 3 \tag{11}$$

$$\ddot{r}_1\cos\theta - \dot{r}_1\dot{\theta}\sin\theta - \dot{r}_1\dot{\theta}\sin\theta - r_1\ddot{\theta}\sin\theta - r_1\dot{\theta}^2\cos\theta$$

■ 1 , 2 , 3 $\Rightarrow$

$$\ddot{S}_2 + \ddot{r}_1\cos\theta - 2\dot{r}_1\dot{\theta}\sin\theta - r_1\ddot{\theta}\sin\theta - r_1\dot{\theta}^2\cos\theta = 0 \tag{12}$$

Then T_1, T_2 and $\ddot{S}$ are found (Eq. 13-18).

$$m_1 g\cos\theta - T_1 = m_1(\ddot{r} - r\dot{\theta}^2) \tag{13}$$

$$-m_2 g\sin\theta = m_2(2\dot{r}\dot{\theta} + r\ddot{\theta}) \tag{14}$$

$$m_2 g - T_2 = m_2\ddot{S}_2 \tag{15}$$

$$T_1 = \frac{2m_1m_2g}{m_1e^{\mu\varphi} + m_2\cos\theta} \tag{16}$$

$$T_2 = \frac{2m_1m_2ge^{\mu\varphi}}{m_1e^{\mu\varphi} + m_2\cos\theta} \tag{17}$$

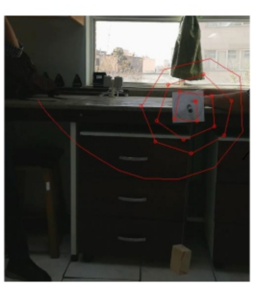
$$\ddot{S} = \frac{m_2g\cos\theta - m_1ge^{\mu\varphi}}{m_1e^{\mu\varphi} + m_2\cos\theta} \tag{18}$$

Now by solving these equations :

4 Experiments and Results

In our experiment(Fig. 4), effective parameters that were investigated are :

1. Mass ratio
2. The angle of extrication
3. The length of extrication
4. Friction between string and bar



Fi. 4: Experiments to find effective parameters

4-1 Mass Ratio and Angle of Extrication

Mass ratio is increased from 1 to 10 , then we investigate each proportion at 5 angles which the best one is (Fig. 5):

$$\frac{M_2}{M_1} = 10$$

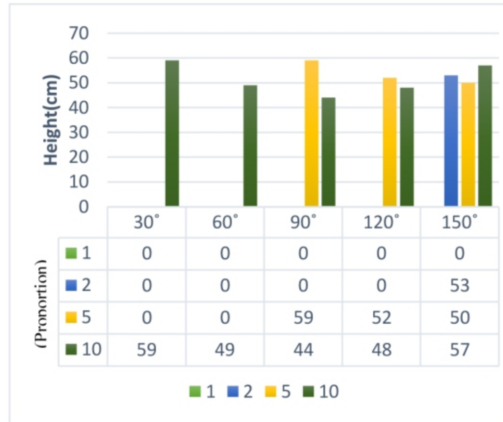


Fig. 5: Mass ratio versus the angle of extrication

4-2 The Height of Extrication

To find the height of extraction, experiment was done at 5 angles and specific mass ratio. A string with a constant length is used which 3 sections are marked on it(Fig. 6).

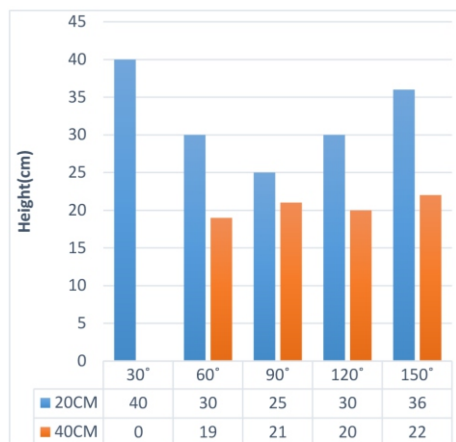


Fig. 6: The height of extrication in different angles

4-3 The Friction Between String and Bar

Six types of surface , paper, banderole, aluminum, cloth, bar and oily surface are used to find the affection of friction in our experiments (Fig. 7).

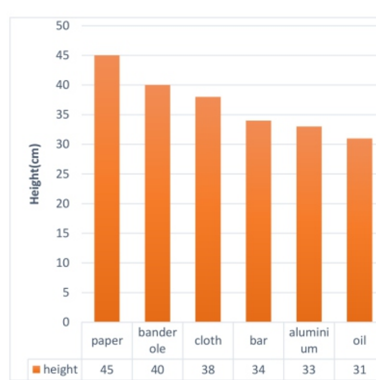


Fig. 7: Different heights in different surfaces

5 Results and Conclusions

By several experiments in this phenomenon, tension of string and acceleration of the elevator were found. Some effective and main parameters are found by tracking the motion of light and heavy loads. The best state is when the mass ratio is 10 and it's in 120˚. Also the friction between bar and string is important parameter which should be considered.

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