Experimental Vibration Analysis of Equivalent Spring Mass System to Find Out Time Period of Oscillation and Validate with Theoretical Method

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Abstract— Natural frequency of vibrating system is mainly depends on equivalent stiffness of spring and equivalent mass of vibrating body. In this paper, measurement of time period has been done theoretically and experimentally. Experimental set up is used to study un-damped vibrations of vibrating system. Theoretical and experimental results are compared with each other. Graphical and analytical values shows that experimental and theoretical time period values are nearly equal to each other. Certain parameters like attached mass to cantilever beam and location of mass attached to cantilever beam has been changed and results are again compared theoretically and experimentally.

Key words: Time Period, Equivalent Mass, Natural Frequency of Oscillations

I. INTRODUCTION

A vibration problem occurs in rotating and moving machine parts. Vibration is sub branch of dynamics which is related with repetitive motions. Apart from machinery surrounding structure also faces vibration hazards because of the vibrating machineries. Common examples of vibrations are vibrations of automobiles, vibrations of locomotives, diesel engines which are mounted on unsound foundation, whirling of shaft, guitar strings and cell phones and swinging pendulum. Vibrations may be useful or sometime they are more hazardous. For example vibration occur i automobile and aircraft engines are undesired because they result in human discomfort to passengers and may cause structural damage due to fatigue, Where as in case of musical instruments vibrations are extremely useful.

Causes of vibrations are mainly as follows;

1) Earthquakes in which excitations may be periodic or random.
2) Unbalanced forces in machineries, these forces are produced within the machine itself.
3) Dry friction between two mating surfaces
4) Winds also cause vibrations of transmission and telephone lines under certain conditions.

II. CALCULATION OF SPRING STIFFNESS (K)

For measuring the spring stiffness (K), we first measured the initial length of spring (δ_1). Now, one end of spring is fixed by screw arrangement as shown in Figure 1 and at other end of spring, pan arrangement is done for adding weight. Then we added mass 1 kg, 2 kg, 3 kg and 4 kg and measured corresponding spring length. The difference between initial length (δ_1) and final length (δ_2) for corresponding mass gives the total deformation ($\Delta\delta$) of the spring. The following Table 1 shows readings of δ1 and δ_2 for corresponding mass varying from 1 kg to 4 kg.

Mass (m) added in Pan	Pan weight	δ1	δ2	Δδ	K	K
(Kg)	(Kg)	(cm)	(cm)	(cm)	(N/cm)	(N/m)
1	1.4	14.5	15	0.5	19.62	1962
2	1.4	14.5	15.5	1	19.62	1962
3	1.4	14.5	16	1.5	19.62	1962
4	1.4	14.5	16.5	2	19.62	1962

Table 1: Spring Stiffness Measurement

As we know, K = load per unit deflection.

$$K = \frac{W}{\Delta\delta} = \frac{mg}{\Delta\delta} \quad (1)$$

Using Equation 1, we calculated the spring stiffness. The spring used for an experiment is having a stiffness of 1962 N/m.

III. TIME PERIOD ($T_{EXPT.}$) MEASUREMENT EXPERIMENTALLY

The experimental arrangement is as shown in Figure 1. Experimental set up is designed to study free and forced damped and un-damped vibrations. It consists of M. S. rectangular beam supported at one end by a trunion pivoted in ball bearing. The bearing housing is fixed to the side member of the frame. The other end of the beam is supported by the lower end of helical spring. Upper end of spring is attached to the screw. The exciter unit can be mounted at any position along the beam. Additional known weights may be added to the weight platform underside the exciter.

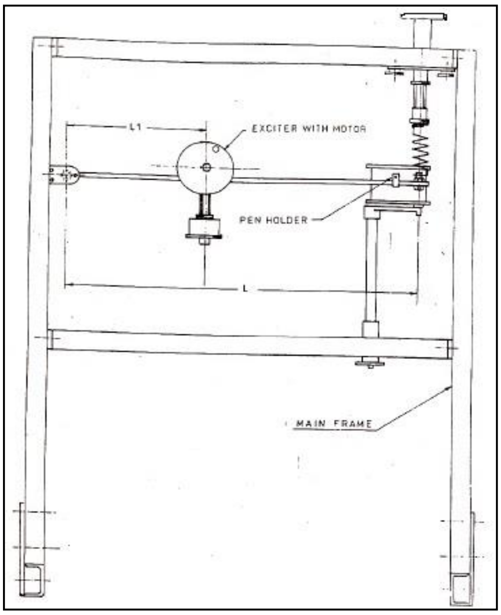

Fig. 1: Experimental set up for time period measurement

Following procedure we have carried out for measuring periodic time of vibrating system:

1) Support one end of the beam in the slot of trunion and clamp it by means of screw.
2) Attach the other end of beam to the lower end of spring.
3) Adjust the screw to which the spring is attached such that beam is horizontal in the above position.
4) Weigh the exciter assembly along with discs and bearing and weight platform.
5) Clamp the assembly at any convenient position.
6) Measure the distance L_1 of the assembly from pivot. Allow the system to vibrate freely.
7) Measure the time for 10 oscillations and find the periodic time and natural frequency of vibrations.
8) Repeat the experiment by varying L_1 and by putting different weights on the platform with proper locking.
9) Slotted weights are clamped to the platform by means of nut, so that weights do not fall during vibrations.

IV. Time Period ($T_{Theoretical}$) Measurement Theoretically

For calculating theoretical time period of vibrating system, it is necessary to calculate equivalent mass (m_e) at the spring having stiffness K. Equivalent mass (m_e) should consider the effect of mass due to weight attached on exciter assembly (w) and weight of exciter assembly along with weight platform (W). As we have measured the distance of exciter assembly from pivot (L_1) and distance of spring from pivot (L). By using Equation 2, we calculated equivalent mass (m_e) at the spring. Equation 4 gives theoretical time period of oscillation of vibrating system and Equation 5 gives corresponding natural frequency in Hertz.

$$m_e = m\left[\frac{L_1}{L}\right]^2 \qquad (2)$$

$$m = w + W \qquad (3)$$

$$T_{Theoretical} = 2\pi\sqrt{\frac{m_e}{K}} \qquad (4)$$

$$f_n = \frac{1}{T} \qquad (5)$$

Where,

m_e = Equivalent mass at the spring. (Kg)
K = Stiffness of the spring in (N/m)
w = Weight attached on exciter assembly (Kg)
g = Acceleration due to gravity = 9.81 m/sec^2
W = Weight of exciter assembly along with weight platform (Kg) =11.55kg.
L_1 = Distance of exciter assembly from pivot
L = Distance of spring from pivot
M = Mass of exciter assembly along with wt. Platform (Kg)
$T_{Theoretical}$ = Theoretical time period of oscillation (seconds)
f_n = frequency of oscillations (Hertz)

Table 2 shows, natural frequencies and theoretical time period of oscillation for added masses varying from 1 Kg to 4 Kg.

w (kg)	W (kg)	m = w +W (kg)	L_1 (cm)	L (cm)	m_e (kg)	Time T (second) for 1 oscillation	Natural frequency f_n (Hertz)	Time T (second) for 10 oscillation Theoretically
1	11.55	12.55	40	93.5	2.30	0.21	4.65	2.15
2	11.55	13.55	40	93.5	2.48	0.22	4.48	2.23
3	11.55	14.55	40	93.5	2.66	0.23	4.32	2.31
4	11.55	15.55	40	93.5	2.85	0.24	4.18	2.39

Table 2: Time Period ($T_{Theoretical}$) Measurement

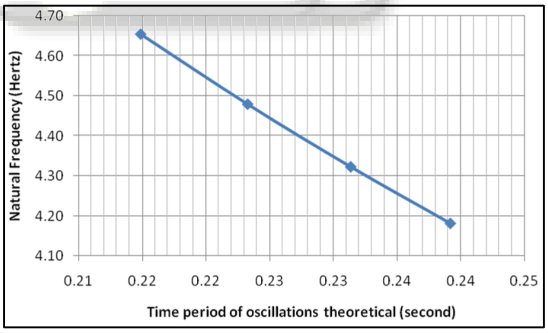

Fig. 3: Comparison of Time Period of Oscillation and Natural Frequency

Graph shown in Figure 3 shows that, as time period of oscillation goes on increasing natural frequency will get reduced. Time period of oscillation is inversely proportional to natural frequency.

V. Comparison of Theoretical and Experimental Time Period

Table 3 shows, comparison of theoretical and experimental time period for mass varying from 1kg to 4 kg.

w (kg)	W (kg)	m = w +W (kg)	L_1 (cm)	L (cm)	m_e (kg)	Time T (seconds) for 10 oscillation Theoretically	Time T(seconds) for 10 oscillation Experimentally
1	11.55	12.55	40	93.5	2.30	2.15	2.17
2	11.55	13.55	40	93.5	2.48	2.23	2.25
3	11.55	14.55	40	93.5	2.66	2.31	2.33
4	11.55	15.55	40	93.5	2.85	2.39	2.42

Table 3: Theoretical and Experimental Time Period

Graph in Figure 4 shows that, Theoretical and Experimental Time Period values are nearly equal to each other.

Now, by varying the distance L_1 we again calculated theoretical and experimental time period. Table 4 shows, corresponding theoretical and experimental time period for length L_1.

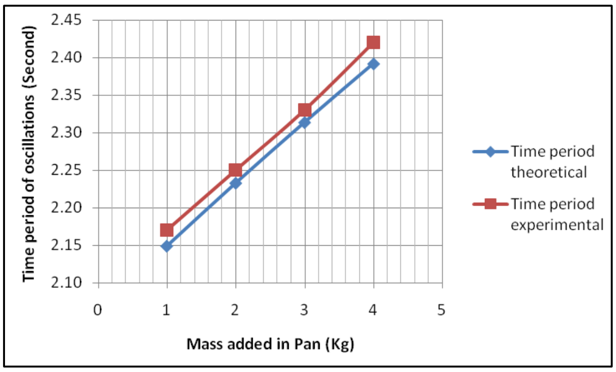

Fig. 4: Comparison of Theoretical and Experimental Time Period

w (kg)	W (kg)	m = w +W (kg)	L_1 (cm)	L (cm)	m_e (kg)	Time T (seconds) for 10 oscillation Theoretically	Time T(seconds) for 10 oscillation Experimentally
1	11.55	12.55	42.5	93.5	2.59	2.28	2.3
2	11.55	13.55	42.5	93.5	2.80	2.37	2.39
3	11.55	14.55	42.5	93.5	3.01	2.46	2.47
4	11.55	15.55	42.5	93.5	3.21	2.54	2.55

Table 4: Theoretical and Experimental Time Period for L_1 = 42.5 cm

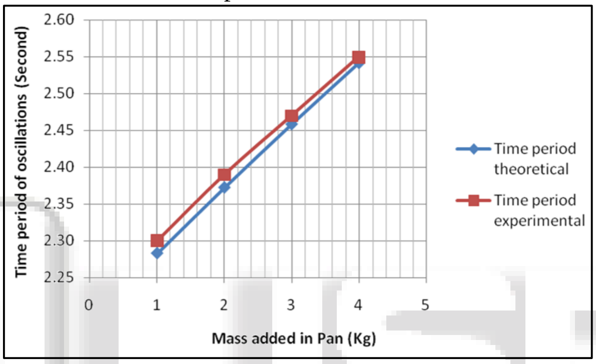

Fig. 5: Comparison of Theoretical and Experimental Time Period for L 1 = 42.5 cm

w (kg)	W (kg)	m = w +W (kg)	L_1 (cm)	L (cm)	m_e (kg)	Time T (seconds) for 10 oscillation Theoretically	Time T(seconds) for 10 oscillation Experimentally
1	11.55	12.55	44.5	93.5	2.84	2.39	2.41
2	11.55	13.55	44.5	93.5	3.07	2.48	2.51
3	11.55	14.55	44.5	93.5	3.30	2.57	2.6
4	11.55	15.55	44.5	93.5	3.52	2.66	2.69

Table 5: Theoretical and Experimental Time Period for L_1 = 44.5 cm

Table 5 shows, corresponding theoretical and experimental time period for length L_1 = 44.5 cm

Graph in figure 6 shows that, Theoretical and Experimental Time Period are nearly equal to each other.

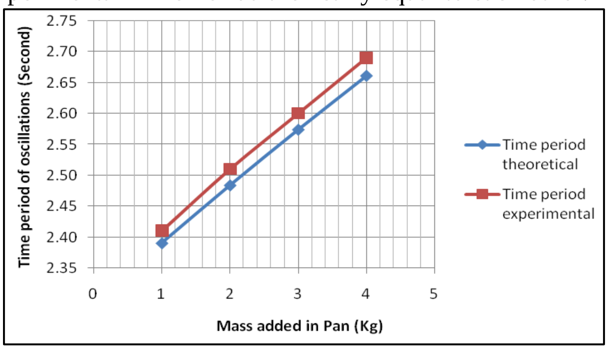

Fig. 6: Comparison of Theoretical and Experimental Time Period for L_1 = 44.5 cm

VI. Conclusion

Theoretical and experimental results are compared with each other. Graphical and analytical values shows that experimental and theoretical time period values are nearly equal to each other. Even after changing parameters like attached mass to cantilever beam and location of mass attached to cantilever beam results not showing much variation for theoretical and experimental values.

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