Experimental Verification of Damping Coefficient and Measurement of Damped Forced Vibrations with Rotating Unbalance of SDOF System

Prof. Dr. S. H. Sawant
Associate Professor

Abstract

When a dynamic system is subjected to a steady-state harmonic excitation, it is forced to vibrate at the same frequency as that of the excitation. Harmonic excitation is often encountered in engineering systems. It is commonly produced by the unbalance in rotating machines, forces produced by the reciprocating machines, or the motion of machine itself. Although pure harmonic excitation is less likely to occur than the periodic or other types of excitation, understanding the behaviour of a system undergoing harmonic excitation is essential in order to comprehend how the system will respond to more general types of excitation. Unbalance in rotating machines is a common source of vibration excitation. This paper deals with experimental setup for determination of damping coefficient and measurement of damped forced vibrations with rotating unbalance of SDoF system.

Keywords-Dynamic System, Harmonic Excitation, Damping Coefficient, Rotating Unbalance.

1. Introduction

Unbalance occurs in a rotating machine when the mass centerline and the geometric center do not coincide with each other. Unbalanced rotors generate vibration which may damage their components. Mass unbalance in a rotating system often produces excessive synchronous forces that reduce the life span of various mechanical elements [1]. Unbalance is the most cause of machine vibration, an unbalanced rotor always cause more vibration and generates excessive force in the bearing area and reduces the life of the machine [2]. In this work a spring-mass system constrained to move in the vertical direction and excited by a rotating unbalanced mass m is considered, as shown in Fig.1. The unbalance is represented by an eccentric mass m with eccentricity e that is rotating with angular velocity ω. Letting x be the displacement of the non-rotating mass (M - m) from the static equilibrium position, the displacement of m is:

$$x + e\sin\omega t$$

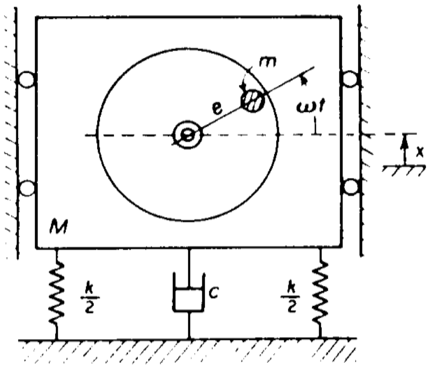

Fig. 1.1 Harmonic Disturbing Force Resulting from Rotating Unbalance

The equation of motion is then:

$$(M-m)\ddot{x}+m\frac{d^2}{dt^2}(x+e\sin\omega t)=-kx-c\dot{x}$$

The steady state solution of above equation is [3]:

$$X=\frac{me\omega^2}{\sqrt{(k-m\omega^2)^2+(c\omega)^2}}$$

2. Experimental Setup

The experimental setup developed to analyse the rotating unbalance consist of eccentric mass of 0.205 Kg. with an eccentricity of 29.5 mm from the centre of main mass.

Fig. 2.1 Experimental Setup for Rotating Unbalance

3. Result and Discussions

1. Theoretical Analysis:

The spring stiffness (k) is obtained experimentally.

Table below shows the mass and deflection of the spring and average value of spring stiffness.

Table 3.1-The Mass and Deflection of the Spring and Average Value of Spring Stiffness.

Sr. No.	Mass attached m (kg)	Weight w (N)	Deflection of Spring	Spring Stiffness (k) N/m	Avg. Stiffness (k) N/m
1	1	9.81	.021	452	451
2	1.5	14.71	.032	451	
3	2.0	19.62	.043	450	

Table below shows the calculations of the logarithmic decrement.

Table 3.2-Calculations of the Logarithmic Decrement

Sr. No.	X_0 (cm)	X_5 (cm)	$\delta = \frac{1}{n}\log_e \frac{Xo}{X_n}$
1	5	5.2×10^{-19}	8.74
2	5	4.038	.042
3	5	1.82	.20

$$\xi_1 = \delta_1{}^2/\sqrt{(4\pi^2 + \delta_1{}^2)}$$

ξ_1 **= .812**

$$X = \frac{F_0}{k}\frac{1}{\sqrt{(1-r^2)^2 + (2\zeta r)^2}}.$$

Where,

$F_0 = 4m_e\,\omega^2$, $r = \omega/\omega_n$ and F0= F_1, F_2, F_3, F_4, F_5

Now for different values of damping ratio the magnification factor and frequency ratio are calculated theoretically. Table 3.3 shows the theoretically calculated values of magnification factor and frequency ratio for damping ratio of 0.802.

Table 3.3- Theoretically Calculated Values of Magnification Factor and Frequency Ratio for Damping Ratio of 0.802

Sr. No.	ω (rad/sec)	ω_n (rad/sec)	U (m)	X (m)	ω/ω_n	X/U
1.	5.23	9.42	0.003598	0.00262814	0.555202	0.730427
2.	7.33	9.42	0.007068	0.00503481	0.778132	0.712371
3.	9.42	9.42	0.011673	0.00727722	1	0.623441
4.	11.52	9.42	0.017457	0.00790934	1.22293	0.453072
5.	13.61	9.42	0.024366	0.00696175	1.444798	0.285715

Table 3.4 shows the theoretically calculated values of magnification factor and frequency ratio for damping ratio of 0.029

TABLE 3.4- Theoretically Calculated Values of Magnification Factor and Frequency Ratio for Damping Ratio of 0.802

Sr. No.	ω (rad/sec)	ω_n (rad/sec)	U (m)	X (m)	ω/ω_n	X/U
1.	5.23	9.42	0.003598	0.00704511	0.555202	1.958015
2.	7.33	9.42	0.007068	0.0352027	0.778132	4.980807
3.	9.42	9.42	0.011673	0.2012529	1	17.24138
4.	11.52	9.42	0.017457	0.05515559	1.22293	3.159485
5.	13.61	9.42	0.024366	0.01924147	1.444798	0.789684

Table 3.5 shows the theoretically calculated values of magnification factor and frequency ratio for damping ratio of 0.0063

Table 3.5- Theoretically Calculated Values of Magnification Factor and Frequency Ratio for Damping Ratio of 0.0.063

Sr. No.	ω (rad/sec)	ω_n (rad/sec)	U (m)	X (m)	ω/ω_n	X/U
1.	5.23	9.42	0.003598	0.00741087	0.555202	2.059668
2.	7.33	9.42	0.007068	0.04271954	0.778132	6.044359
3.	9.42	9.42	0.011673	0.92640225	1	79.36508
4.	11.52	9.42	0.017457	0.06688914	1.22293	3.831619
5.	13.61	9.42	0.024366	0.02029259	1.444798	0.832823

Fig.3.1 shows the theoretically calculated values of magnification factor and frequency ratio for damping ratio of 0.0063

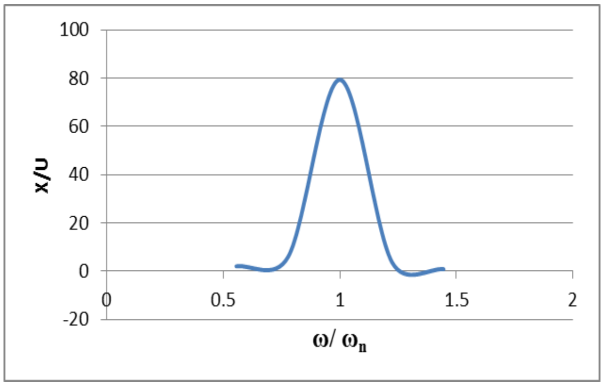

Fig.3.1- Theoretical Graph between Magnification Factor and Frequency Ratio

2. Experimental Analysis:

Table 3.6 shows the experimentally measured values of magnification factor and frequency ratio for damping ratio of 0.0068

Table 3.6- Experimentally Measured Values of Magnification Factor and Frequency Ratio for Damping Ratio of 0.0068

Sr. No.	ω (rad/sec)	ω_n (rad/sec)	U (m)	X (m)	$\omega/\ \omega_n$	X/U
1.	5.23	9.42	0.003598	0.00333	0.555202	0.925492
2.	7.33	9.42	0.007068	0.01146	0.778132	1.621468
3.	9.42	9.42	0.011673	0.592	1	50.71677
4.	11.52	9.42	0.017457	0.02253	1.22293	1.290589
5.	13.61	9.42	0.024366	0.01433	1.444798	0.588114

Fig.3.2 shows the experimentally measured values of magnification factor and frequency ratio for damping ratio of 0.0068

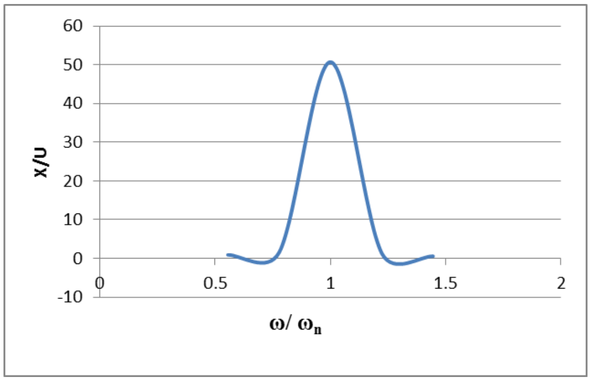

Fig.3.2 Experimental Graph between Magnification Factor and Frequency Ratio

Fig.3.3 shows the comparative graph of magnification factor and frequency ratio for damping ratio of 0.0068 for experimental and theoretical method.

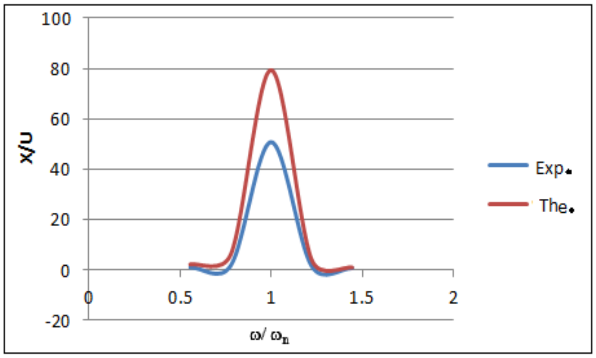

Fig.3.3- Comparative Graph of Magnification Factor and Frequency Ratio

CONCLUSION

It is seen from the theoretical and experimental frequency resonance curves that a response of a particular system at any particular frequency is lower for higher value of damping. Also at very high frequency the magnification tends to zero or the amplitude of vibration became very small and at resonance ($\omega = \omega_n$) the amplitude of vibration becomes excessive for small damping and decrease with increase in damping.

The slight variations in the theoretical and practical curves may be due to inaccuracies in the measurement system caused by instrument errors and manual errors and due to nonlinearities present in the system.

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