ME3491 THEORY OF MACHINES

UNIT V NOTES

5.5 Forced Vibration

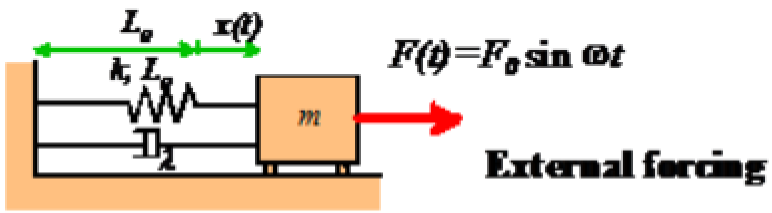
When a vibration takes place under the influence of external periodic force then it is called a forced vibration. Also when the body vibrates due to an external periodic force other than its own natural frequency then we can say that it is forced vibration.

inally, we solve the most important vibration problems of all. In engineering practice, we are almost invariably interested in predicting the response of a structure or mechanical system to external forcing. For example, we may need to predict the response of a bridge or tall building to wind loading, earthquakes, or ground vibrations due to traffic. Another typical problem you are likely to encounter is to isolate a sensitive system from vibrations. For example, the suspension of your car is designed to isolate a sensitive system (you) from bumps in the road. Electron microscopes are another example of sensitive instruments that must be isolated from vibrations. Electron microscopes are designed to resolve features a few nanometers in size. If the specimen vibrates with amplitude of only a few nanometers, it will be impossible to see! Great care is taken to isolate this kind of instrument from vibrations. That is one reason they are almost always in the basement of a building: the basement vibrates much less than the floors above.

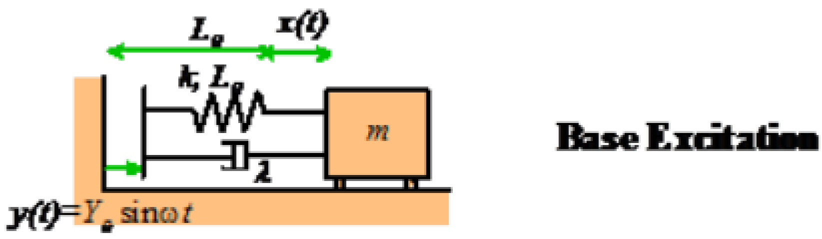
We will again use a spring-mass system as a model of a real engineering system. As before, the spring-mass system can be thought of as representing a single mode of vibration in a real system, whose natural frequency and damping coefficient coincide with that of our spring-mass system.

We will consider three types of forcing applied to the spring-mass system, as shown below:

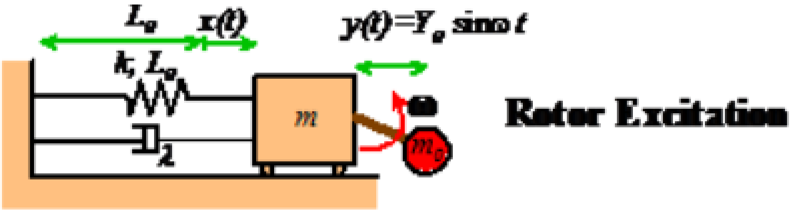
External Forcing models the behavior of a system which has a time varying force acting on it. An example might be an offshore structure subjected to wave loading.



Base Excitation models the behavior of a vibration isolation system. The base of the spring is given a prescribed motion, causing the mass to vibrate. This system can be used to model a vehicle suspension system, or the earthquake response of a structure.



Rotor Excitation models the effect of a rotating machine mounted on a flexible floor. The crank with small mass m_b rotates at constant angular velocity, causing the mass *m* to vibrate.



5.6 Torsional vibration

Torsional vibrations are an example of machinery vibrations and are caused by the superposition of angular oscillations along the whole propulsion shaft system including propeller shaft, engine crankshaft, engine, gearbox, flexible coupling and along the intermediate shafts.

Torsional vibrations are angular vibrations of an object and rotational vibration is simply the dynamic component of the rotational speed.

5.7 Damped vibration

When the energy of a vibrating system is gradually dissipated by friction and other resistances, the vibrations are said to be damped vibrations. The vibrations gradually reduce or change in frequency or intensity or cease and the system rests in its equilibrium position.

5.8 Critical Speed of a Shaft Definition

The whirling speed or critical speed of a shaft is the speed at which a spinning shaft will tend to vibrate strongly in the transverse direction if rotated horizontally. In other terms, the crucial speed or whirling speed is the speed at which resonance occurs. As a result, we may say that shaft whirling happens when the natural frequency of transverse vibration equals the frequency of a rotating shaft.

5.9. Harmonic Forcing

The term harmonic forcing refers to a spring-mass system with viscous damping excited by a sinusoidal harmonic force.F = F 0 sin.

5.10 vibration isolation

Vibration isolation is a commonly used technique for reducing or suppressing unwanted vibrations in structures and machines. With this technique, the device or system of interest is isolated from the source of vibration through insertion of a resilient member or isolator.

Vibration isolation is used to manage and mitigate unintended vibrations that can waste energy, degraded operation, and significantly limit the operational lifespan of physical components.

Problem

A mass suspended from a helical spring vibrates in a viscous fluid medium whose resistance varies directly with the speed. It is observed that the frequency of damped vibration is 90 per minute and that the amplitude decreases to 20 % of its initial value in one complete vibration. Find the frequency of the free undamped vibration of the system.

Solution.

Given : f d = 90/min = 90/60 = 1.5 Hz We know that time period,

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$$t_p = 1/f_d = 1/1.5 = 0.67 \text{ s}$$

Let x_1 = Initial amplitude, and

x_2 = Final amplitude after one complete vibration

$= 20\%\ x_1 = 0.2\ x_1$

We know that

$$\log_e\left(\frac{x_1}{x_2}\right) = a.t_p \quad \text{or} \quad \log_e\left(\frac{x_1}{0.2\,x_1}\right) = a \times 0.67$$

$$\therefore \quad \log_e 5 = 0.67\,a \quad \text{or} \quad 1.61 = 0.67\,a \text{ or } a = 2.4 \quad \ldots (\because \log_e 5 = 1.61)$$

We also know that frequency of free damped vibration,

$$f_d = \frac{1}{2\pi}\sqrt{(\omega_n)^2 - a^2}$$

or

$$(\omega_n)^2 = (2\pi \times f_d)^2 + a^2 \quad \ldots \text{(By squaring and arranging)}$$

$$= (2\pi \times 1.5)^2 + (2.4)^2 = 94.6$$

$$\therefore \quad \omega_n = 9.726 \text{ rad/s}$$

We know that frequency of undamped vibration,

$$f_n = \frac{\omega_n}{2\pi} = \frac{9.726}{2\pi} = 1.55 \text{ Hz}$$