Impact of Mechanical Vibration

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Abstract- **The Mechanical phenomena where any motion that occurs about some equilibrium point is known as vibration. It is also observed as any shaky Motion. Clearly, vibration can thus be Ruinous which is the reason for its unwished-For. However, it can also be good and useful as observed in some mechanical and construction equipment. Vibration can be observed in pendulum set in motion, a plucked guitar string, vehicles driven on rough terrain and geological activities like earthquakes. It is also observed in vibratory conveyors, washing machines, electric massaging units, compactors, hoppers, and the like. Thus the reason for the vibration study is to minimize the effect of vibration to zero through proper design of machines and their Manufacturing's. In this connection, the mechanical engineer tries to design the engine or machine to minimize the vibrational effect, while the structural engineer tries to design the supporting structure to ensure that the effect of vibration is safe. Despite its damaging effects, vibration can be used profitably in several consumer and industrial applications. The efficiency of certain machining, casting, forging, and welding processes has been found to be improved by vibration. It is also employed to simulate earthquakes for geological research and to conduct studies in the design of nuclear reactors. Clearly, vibration studies focused on the nasty of vibration and how to reduce its effect. It may open a floodgate of new investigations into the effect of the various vibration types which may in turn lead to new designs and fabrication of appropriate engineering strategies to governor and shrink to the simplest minimise the harmful effect of the various vibration types.**

Index terms- **Vibration, Shaky motion, Vibration in engineering**

INTRODUCTION

Vibration can be felt in most human activities like hearing, seeing, breathing, walking, and speaking. Hearing because the eardrum vibrates, seeing because light waves are involved in vibration. Breathing is due to the vibration of the lungs, walking is due to the oscillatory motion of legs/hands, and speaking is due to the oscillatory motion of tongues and larynges. According to Beards (1995), early studies of vibration concentrated on the understanding of the natural phenomena and developing mathematical theories that described the vibration of physical systems. However, recent investigations motivated by engineering research on the applications of vibration revealed that most vibrational problems are due to inherent variation in the engines of machines/devices. The variation may result from faulty design or faulty manufacturing. Variation in diesel engines, for example, can cause ground waves sufficiently powerful to create an annoyance in urban areas. The wheels of some locomotives can raise more than a centimetre off the track at high speeds due to variation. Vibrations cause spectacular mechanical failures. The structure or machine component subjected to vibration can stop functioning because of material fatigue resulting from the cyclic variation of the induced stress. Furthermore, vibration causes more wear and tear to the parts of the machine such as bearings and gears and also produces excessive noise. In metal cutting, vibration can cause Noise, which leads to a faulty surface finish. The phenomenon called Resonance leads to excessive deflections and failure (Thorby, 2008). Kinds of literature abound with accounts of system failures brought about by resonance and excessive vibration of components and systems.

Also, testing the effect of vibration now becomes a Standing order in the design and development of most engineering systems because of the harmful effects. Humans act as an essential part of many engineering systems. The conduction of vibration to humans results in embarrassment and loss of productivity. For instance, discomforts experienced by passengers in an aircraft when the frequencies of vibration of the wings of the aircraft correspond to the natural frequencies of the human body or organs.

it is well known that the resonant frequency of the human intestinal tract (approximately 4-8Hz) should be kept away anyhow when designing very high-performance aircraft and reusable launch vehicles because sustained exposure can cause serious internal trauma (Leatherwood and Dempsey, 1976). The vibration of the wing of aircraft for an extended period may lead to large vibration amplitudes which are a potential cause of the crash in aircraft with attendant fatalities. Wing vibrations of this type are usually associated with the wide variety of flutter phenomena caused by fluid-structure interactions. The most famous and commonly known engineering tragedy incident of all time was the Tacoma Narrows Bridge disaster in 1940. It occurs due to the same type of self-excited vibratory behaviour that occurs in aircraft wings. According to Vyas (2003), the Vibration and noise generated by engines cause irritation to people and, sometimes, damage to property. Vibration of instrument panels can cause their failure or difficulty in reading the meters .

Edelugo (2009) state that Vibration systems are of following types - undammed vibration, forced undammed vibration, free, damped vibration and forced damped vibration for one, two or more degrees of freedom cases. He also prove the phenomena of vibration involve the interaction between potential energy and kinetic energy. A vibrating system must have a component that stores potential energy (spring) and releases kinetic energy in the form of motion (vibration) of a mass. The motion of the mass then gives up kinetic energy to the potential energy storing device (damper). Vibration can occur in many directions and can be the result of the interaction of many objects. He concludes that vibration is therefore modelled mathematically based on fundamental principles such as Newton's laws and analysed using results from calculus and differential equations. Displacement, velocity and acceleration vectors describes the fundamental Kinematic quantities. In translational motion, displacements are defined as linear distances and in rotational (torsional) motion, displacements are defined as angular motions.

Vyas (2003) opined that excess vibration shortens equipment lifespan. Since vibration in engineering cannot be eliminated but can be controlled to a minimum, therefore vibration concept is considered as paramount in the design of mechanical engineering equipment.

MODEL OF THE VARIOUS TYPES OF VIBRATION

Free Undamped Vibration

ma + kd = 0

Where 'd' is displacement, 'k' is spring constant, 'm' is the mass and 'a' is the acceleration.

Free, Damped Vibration

0 = kx + by + mz

Where 'kx' is spring force, by is the damping force, 'mz' is inertial force and 'b' is the damping coefficient.

Forced, Damped Vibration

F(t) = kx + by + mz

where F(t) is the driving force (external)

Forced, Undamped Vibration

F(t) = kx + mz

WORKED EXAMPLES OF THE VARIOUS TYPES OF VIBRATION

Free, Undamped Vibration

Example

A spiral spring with its axis horizontal is fixed to a vertical solid wall, a football of mass 6 g is thrown horizontally at 12 m/s against the spring and compresses 2 mm

a) Estimate the spring constant.

b) After leaving the spring, the ball falls to a floor which is 2m below the spring. How far from the wall will it strike the floor?

Solution:

Momentum change = Force = 6*10-3*12 = 0.072 N

Kx = -mz = Force (Free, undamped vibration)

K (0.002) = 0.072

K = $\frac{0.072}{0.002}$ = 32 N/m.

ωn = $\sqrt{\frac{k}{m}}$ = $\sqrt{\frac{32}{0.006}}$ = 73.02 rad/s where ωn = natural frequency.

V = $\omega\sqrt{A^2 - x^2}$

A2 = $\frac{v^2}{\omega^2} + x^2 = \frac{144}{5331.92} + 4 = 4.027$

A = $\sqrt{4.027}$ = 2.007 m where A = amplitude.

Free, damped vibration

Example

A vibrating system consisting of a weight 0.6 N and stiffness 13 N/m is viscously damped such that the ratio of every consecutive amplitude is 1.00 to 0.98. Determine

- The natural frequency of the damper
- The logarithmic decrement
- The damping factor
- The damping coefficient.

Solution:

$\omega n = \sqrt{\frac{k}{m}} = \sqrt{\frac{12}{0.06}} = 14.71\ \frac{rad}{sec}$ where ωn = natural frequency and g = 10.

$$\sigma = ln\frac{x_1}{x_2} = \ ln\frac{1}{0.98} = 0.02\ where\ \sigma = logarithmic\ decrement.$$

$$ב = \sqrt{\frac{\sigma^2}{4\pi^2 + \ \sigma^2}} = \sqrt{\frac{0.0004}{4(9.87) + \ 0.0004}} = \sqrt{\frac{0.0004}{39.4804}} = \ \sqrt{10.1(10^{-6})} = 0.00318 = 3.18(10^{-3})\ where\ ב = damping\ factor.$$

$$b = 2mב\omega_n = 2(0.06)(0.00318)(14.71) = \ 0.0056 = 5.6(10^{-3})\frac{Ns}{m}.$$

Forced, Damped Vibration

Example

A small motor driven compressor set weighs 60 N and causes each of the four rubber isolators on which it is mounted to deflect 2.5 mm. The speed of motor is 750 rpm. 750 rpm. The compressor has a 5 mm stroke. The piston and the reciprocating parts weigh 0.6 N and for the purpose of this problem, the reciprocating motion of the piston is assumed to be simple harmonic. Determine the amplitude of vertical motion at the operating speed. Assume damping factor of rubber is 0.2.

Solution:

$$k = \frac{W}{\delta} = and\ \omega_n = \sqrt{\frac{k}{m}}\ where\ \delta = deflection, k = stiffness, W = weight\ and\ \ \omega_n = natural\ \ frequency.$$

$$k = \frac{60}{0.0025(4)} = 6000\ N/m$$

$$\omega_n = \sqrt{\frac{6000}{6}} = 31.62\frac{rad}{s}\ where\ g = 10$$

$$\omega = \frac{2\pi(750)}{60} = 78.57\frac{rad}{s}$$

$$F_0 = me\omega^2\ and\ \omega = \ \sqrt{\frac{g}{l}} = \ \sqrt{\frac{10}{0.005}} = 44.72\frac{rad}{s}$$

$$F_0 = 0.6(2000) = 1200N\ where\ F_0 = initial\ force$$

$$A = \frac{F_0/K}{\sqrt{\left[1 - \left(\frac{\omega}{\omega_n}\right)2\right]2 + \left[2ב\frac{\omega}{\omega_n}\right]2}} = \frac{1200/6000}{\sqrt{\left[1 - \left(\frac{78.57}{31.62}\right)2\right]2 + \left[2(0.2)(\frac{78.57}{31.62})\right]2}} = \ \ 0.038\ m$$

$where\ A = amplitude\ and\ ב = damping\ factor$

Torsional Vibration

The vibration of a rigid body about a specific reference point that is measured in terms of angular coordinates is known as Torsional Vibration. There are various reasons behind restoring moment in Torsional Vibration. Some of the reasons may either be due to the unbalanced moment, the torsion of the elastic member, a force or couple. Examples of torsional vibration include the rotor system (fixed at one or both ends), the geared system and the shaft system (deflection, critical speed and equivalent shaft).

Example:1 A shaft of composite sections has a total length of 1.50 m. One section is 50% as long as the other with diameter of 15 cm and 35 cm respectively. Determine the equivalent shaft length.

Solution:

$$L_2 = 0.50L_1 \; and \; L_1 + L_2 = 1.50 \; m. Thus \; L_1 = 1 \; m \; and \; L_2 = 0.50 \; m$$

For constant diameter 0.15 m (d2), the shaft length is given by

$$L = L_2 + \frac{d_2^4}{d_1^4} L_1 = 0.50 + \frac{0.15^4}{0.35^4} \; 1 = 0.53 \; m$$

For constant diameter 0.35 m (d1), the shaft length is given by

$$L = L_1 + \frac{d_1^4}{d_2^4} L_2 = 1 + \frac{0.35^4}{0.15^4} \; 0.5 = 5.33 \; m$$

DISCUSSION

From the typical and worked examples, the free, Unimpeded vibration stances little or no risky effect. With Some improvements in the system, efficiencies like the spring and the moving body exhibiting simple harmonic motion (SHM) in the worked examples can be improved. Both items are without damping and external excitation.

For the forced, damped vibration, external force or excitation press into service in adding to damping. The excitation leads to resonance with its associated Destructive effect. The given examples deal with the amplitude, transmissibility, and transmitted forces due to the external excitation. It is worth to note that almost all Machine vibrations are due to either repeating (exciting)forces, imbalance, resonance, or some combination of these causes. The origins of vibration of this nature tends to breakdowns, failures, and sometimes losses of machinery and equipment.

When talking about forced, undammed vibration, the vibrational effect due to shaky motion is conducted without any damping. Thesis similar to an earthquake where the earth shock is transmitted to infrastructures without any control to its Devastating effect.

In the free-damped vibration, damping is introduced. There are three main special cases of damping namely under, critical, and over damping. We also have damping coefficient and damping factor. Dampers should be so designed with appropriate damping coefficient and damping factor to address the special cases of damping whenever a vibration type of this nature occurs. The worked examples indicate the need to determine the damping coefficient and the damping factor of the damper as well as its logarithmic difference for effective control of vibration of this nature.

This suggests a revisit to the design and fabrication of appropriate devices like a damper to control and reduce to a minimum the harmful effect of vibration. A similar design of vibration sensors should be revisited to monitor and report tremors (tectonics). The harmful effect of earthquakes and flooding may be mitigated through proactive action as a result of a timely reports of the same. There is therefore the need to seek the intervention of divine providence.

CONCLUSION

The purpose of vibration study is to minimize the vibrational effect to zero by appropriate design of machines and their Mountings. In this construction, the mechanical engineer attempts to design the engine or machine to minimize difference while the structural engineer tries to design the secondary structure to ensure that the effect of the imbalance will be harmless. In spite of its negative effects, vibration can be developed profitably in several consumer and industrial applications.

The significance of vibration is not restricted to engineering systems but extends to other areas of human existence. The advantages of vibration appear to exceed its disadvantages. This is mainly due to the proper management of the advantages of vibration by deploying sound engineering principles/practices. It is hoped that the worked examples as well as the discussion within will encourage a floodgate of new investigations into the various vibration types with the view to designing and fabricating new devices to control to the barest minimum the devastating effect of vibration.

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