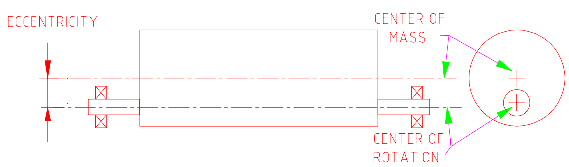
1.9 Vibration

Vibration in equipment is the result of unbalanced forces. The transference of unbalanced forces through equipment into neighbouring structures causing them to shake is vibration. The motion of a body is limited by what connects it to a machine and the walls in which it moves. Every time there is a change of direction unbalanced forces produce a shock. This shock travels throughout the machine and is transmitted to all connected items. Out-of-balance is corrected by adding or removing material so that when the equipment is operating the unbalance is controlled to an acceptable level.

The rate of vibration is called the frequency. It is measured in cycles per second and has the units Hertz. A four-pole electric motor rotates at about 1500 RPM. This is 25 cycles per second or 25 Hertz. Vibration caused by an external applied force is known as a forced vibration because the mass oscillates at the frequency of the external force. An example is the shake produced by the moving pistons and crankshaft in a car engine.

The four methods of vibration control are listed below.

Reduce or eliminate the exciting force by balance or removal.
Use sufficient damping to limit amplitude.
Isolate the vibration source from the surrounds by using spring mounts of appropriate stiffness.
Introduce a counterbalancing force opposite in phase to the exciting force.



Most importantly every moving mass must be balanced about its center of rotation. Every rotating mass must be balanced to an acceptable standard. Out–of-balance rotors cause vibration because the center of mass of the rotor is eccentric (not running true) to its center of rotation. The spinning, off-center mass is continually being flung outward. The machine's bearings hold the mass in place and react against the developed forces. Vibration results as first the mass is on one side of the bearings and then it is on the other. Balancing aims to distribute the mass evenly about the running center. The drawing above shows eccentricity between the center of mass and the center of rotation.

Materials such as rubber dampen shaking. The rubber flexes and absorbs the movement within itself. Rubber makes a good vibration damper. Because rubber cannot compress much to accommodate movement, rubber dampers are normally used for low amplitude, high frequency vibration where noise transference is a problem. Shock absorbers are used for large amplitude, low frequency situations where springs alone would produce bouncing. An example is in car suspensions.

A vibrating mass can also be isolated from its surroundings by springs. The springs deflect under the shaking body. Installing isolation springs make the spring's natural frequency the governing frequency for forced vibration transfer. How far a spring will compress under load depends on its stiffness. Altering the spring stiffness controls the amount of vibration transferred to the attachment. Too stiff will transmit vibration, while insufficient stiffness will cause bounce. The correct spring stiffness can be found using charts available from specialist vibration control companies.

An out-of-phase mass is a method not often used to control vibration. It is possible to use a weight with an opposite vibration pattern to negate the out-of-balance forces. This method has been used in motor car engines where a shaft with an eccentric mass is spun in the opposite direction to the crankshaft.

Causes of out-of-balance
The table below lists some common causes for unbalance.

a)	Bent or bowed between support bearings
b)	Overhung weight bends shaft under gravity
c)	Unevenly distributed solid or liquid inside rotor
d)	Loose parts on the rotor
e)	Eccentrically manufactured diameters on the rotor
f)	Misalignment of the drive train to the rotor axis
g)	Loose drive couplings flop about
h)	Loose tolerances between assembled parts on rotor
i)	Shoulders on rotor are made out-of-square to axis
j)	Voids or cavities within the rotor
k)	Misalignment of bearings force shaft to bow