1.1 Introduction to vibration control:

When a system possessing mass and elasticity is disturbed from its equilibrium position by the application of an external force and then released it commences to ***vibrate*** or ***oscillate***. Thus most engineering machines and structures experience vibration to some degree, and their design generally requires consideration of their oscillatory behavior. Work done by the excitation force in producing the initial disturbance is against the internal elastic force which resists deformation. This work is stored as elastic or strain energy so that when the external force is removed, the internal elastic forces tend to restore the body to its equilibrium position. The whole of this elastic or strain energy is converted into kinetic energy at the instant the body reaches its original equilibrium position. As a result, the motion of the body continues until the whole of the kinetic energy is absorbed in doing work against the internal elastic forces and the emery in the system is again strain energy. Again the system begins to return to the original equilibrium position and oscillation or vibration continues indefinitely. The vibration in which, after the initial disturbance, no external forces acts and the motion is maintained by the internal elastic forces, termed as ***free vibration*** or ***natural vibration***. The vibration in which, after the initial disturbance, the motion is maintained by the external excitation forces, the vibration then has the same frequency the applied force, termed as ***forced vibration.*** If the frequency of excitation coincides with one of the natural frequencies of the system, a condition of ***resonance*** is encountered, and dangerously large oscillations may result. In the real life, the energy possessed by the system is gradually dissipated in overcoming internal and external resistances to the motion and system finally comes to rest in its original equilibrium position, termed as ***damped vibration.***

Unnecessary vibration may cause excessive wear of machine components, formation of cracks, loosening of fasteners, wasting energy and creating unwanted sound, noise etc. Excessive resonant vibration of the mechanical system may lead to its complete failure. For example, the oscillatory motions of engines, electric motors, or any mechanical device in operation are typically unwanted

Elimination or reduction of unwanted vibration is necessary to prevent failure, wear & tear and to increase life of the system. The elimination or reduction of unwanted vibration of the system to an acceptable limit is called ***vibration control***.

Vibration can be controlled by several methods.

- ***Control at Source:*** Reducing the magnitude of the external excitation source.
- ***Control at System:*** Controlling system parameters and changing of system configuration.
- ***Introduction of energy-dissipating mechanism:*** Introducing vibration absorbers between them
- ***Reduction of force or motion transmission:*** Isolating the system from the source of excitation using vibration isolators.

The external source excitation force for vibration may be due to unbalanced reciprocating component, large impact forces or non-uniform load distribution on structures. The magnitude of external source of excitation can be controlled by properly balancing of rotating and reciprocating component of the machine.

The unwanted vibration may be controlled by changing the system configuration. The system parameters such as inertia, stiffness damping parameters can be changed to control vibration. This method of vibration control is called ***dynamic vibration control***. The isolation of the system form the excitation source can be used to control vibration. The isolators or the absorbers reduce the transmission of excitation force from source to the system. This way transmission of motion from source to the system is also reduced.

Perfect balancing of the machine is not possible. Achieving perfect balancing will cost very high. Natural source of excitation such as earthquake, waves in an ocean, wind-induced vibration can not be controlled. Changing system parameters can not be achieved easily due to requirements of the system.

Rotating machines are often subjected to fluctuating torsional loads that can cause noise and vibration difficulties, for example, gear rattle and fatigue failure. Many methods are used to reduce torsional vibrations, including the addition of flywheels and tuned vibration dampers. These methods, however, have some drawbacks. Flywheels increase the system inertia, which reduces system responsiveness, while torsional dampers dissipate energy and work at only a single frequency (or a small set of resonant frequencies). Another effective method for reducing torsional vibrations is the use of centrifugal pendulum vibration absorbers (CPVAs). These are masses mounted on the rotor in such a manner that they are free to move relative to it along prescribed paths, and whose motions are used to work against the applied fluctuating torque, thereby reducing torsional vibration of the rotor. Further depending upon the control strategy followed the vibration control procedure can be classified into two categories

- Passive Vibration Control
- Active Vibration Control

1.1.1 Passive vibration control:

When the control system performs its functions without any external power supplied to it, termed as ***passive vibration control***. Passive vibration control techniques include traditional vibration dampers (energy dissipaters), shock absorbers, and the like, all of which attempt to use friction to convert vibration into heat. In passive vibration control, the system has constant properties. The control system has no any sensor, signal processor and actuator, thus there is no any feedback signal. It is useful to be able to prevent vibration energy from traveling from source of excitation to the mechanical system. In the dynamics of rotating and reciprocating machinery, forces are often generated that cause undesirable oscillatory torques at frequencies that are multiples of the nominal rotation rate. These torques results in torsional oscillations which introduce roughness and fatigue difficulties. Perhaps the most challenging vibration control issues arise in space missions that involve satellites with highly sensitive instrumentation packages. To function correctly, these packages must be supported on structures where the vibration levels have been reduced to extremely low levels (micro-vibrations). In such cases, there is a need to support instruments spaced tens of meters apart using structural booms, with the relative motions between their ends being restricted to microns over wide ranges of excitation frequency. The most common treatment for such problems is to use anti-vibration mountings or to coat the structural elements with heavy viscoelastic damping materials with consequent weight and cost penalties. But these are not sufficient for the increasing requirements for a vibration-free environment. Centrifugal pendulum vibration absorbers are a type of tuned dynamic absorber.

1.1.2 Active vibration control:

When the control system perfumes its functions with external power supply, termed as ***active vibration control.*** It is the active application of force in an equal and opposite fashion to the forces imposed by external vibration. Active Vibration Control can be used for reducing vibration in helicopters, offering better comfort with less weight than traditional passive technologies. The aim of active vibration control is to reduce the vibration of a mechanical system by the automatic modification of the system's structural response. Many precision industrial processes cannot take place if the machinery is being affected by vibration. The active control system may be electromechanical, electrofluidic, electromagnetic or piezoelectric. The typical system uses several components:

- A massive platform suspended by several active drivers.
- Three accelerometers that measure acceleration in the three degrees of freedom.
- An electronic amplifier system that amplifies and inverts the signals from the accelerometers.
- For very large systems, hydraulic components that provide the high drive power required.

Different types of sensors are available to create feedback signals based on the displacement, velocity or force. The signal processor may consist of a passive mechanism such as mechanical linkage or an active electronic network. The actuator may be a mechanical system, fluidic system or piezoelectric and electromagnetic force generating systems. Active vibration control is more complicate then passive vibration control.

1.2 Vibration Absorbers:

The amplitude of vibration will be very large if a system experiences a force whose excitation frequency coincides with the natural frequency of the machine or the system which is referred to as resonance. Vibration neutralisers can be used in reducing the vibration levels of the machines or systems. The vibration neutralisers or absorbers are designed such that the natural frequency(-ies) of the resulting system is far away from the excitation frequency.

In the present analysis our main objective is to classify various vibration absorbers according to their assembly and to analyse their performance so as to minimise the amplitude of the main mass system and primarily to avoid the condition of resonance.

In case of damped vibration absorber optimum damping is main criterion to play the deciding role [1], which is being discussed in the case of damped vibration absorber. The untuned viscous vibration absorber widely used in torsional vibration problem [2], is also being discussed.

The effect of non-linearity of the spring is also significant because if the amplitude of vibration becomes large the component of the system starts behaving non-linearly [3]. Effectiveness of the linear vibration absorbers is limited to the narrow frequency range. This range is very often not enough for the changes in the speed due to load or supply variations. To cut across this draw back the use of non-linearity has also been suggested.

Classification of vibration absorbers

Vibration absorbers can be classified as

- Frahm's dynamic vibration absorber.
- Damped vibration absorber.
- Centrifugal Pendulum vibration absorber.
- Untuned Torsional vibration absorber.

1.2.1 Frahm's Dynamic Vibration Absorber:

The undamped vibration absorber, also known as Frahm's dynamic vibration absorber is extremely effective for constant speed machine operation. Dynamic absorber is generally used when primary system except the absorber is nearly in resonance with the excitation. It is basically used to tune up dynamic absorber to the frequency slightly lower than the forcing frequency to avoid the resonance that lye above the natural frequency of the system. Similarly if the natural frequency of the primary system is above the forcing frequency it is required to tune up dynamic absorber to the frequency slightly greater than the forcing frequency.

1.2.2 Damped vibration absorber:

The damped vibration absorber is very useful in reducing the amplitude of vibration near the resonance conditions and the optimum damping plays the major role.

1.2.3 Centrifugal Pendulum vibration absorber:

In case of torsional system having torsional oscillations superimposed upon the rotation it is possible to design an absorber which can be used for different speed of rotation. That is basically the centrifugal pendulum vibration absorber.

1.2.4 Untuned Torsional Vibration Absorbers:

The distributing frequencies of torsional vibration oscillation are proportional to rotational speed. However there is generally more than one such frequencies and the centrifugal pendulum vibration absorber has the disadvantage that the several pendulums tuned to order number of the disturbance have been used. As compared to centrifugal pendulum vibration absorbers the untuned viscous torsional damper is effective over the wide operating range.