Design and Testing of Stockbridge Vibration Dampers

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Concept of Wind Induced Oscillations

Oscillations in conductors occur due the following phenomena:

1. Aeolian or Vertical Vibrations : This is the most common type of vibration that results due to vortex shedding under laminar flow of wind. These are low amplitude medium frequency (3 – 60 Hz for wind speeds of 1-8 m/s). Sometimes, additional sinusoidal waves of different frequencies arise on the line, corresponding to a higher mode of vibrations. These vibrations are in the vertical plane and exert continuous alternating bend stresses on the conductor strands and eventually may lead fatigue failure of the conductor. Purview of this article is to cover protection of conductor from Aeolian Vibration

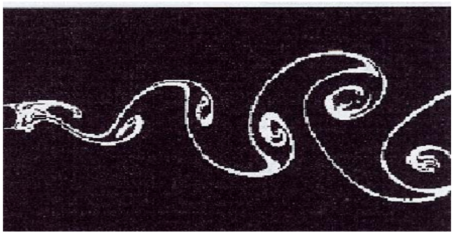


Fig: Vortex shedding from a circular body

2. Galloping: It is also termed as Long wave vibrations and is characterized by low frequencies of 0.1 to 1 Hz. This phenomenon is most common when there is a sleet covering of the cable. Ice coating creates irregular edges and surfaces, which disturb the airflow, which breaks away at these points to induce a certain self-excitation. Thus the system becomes susceptible to vibrations subject to resonance. This effect is not so pronounced in India. Conditions that are conducive for galloping are – Low pressure area with High winds, temperature between 0 and -5 ˚C.

3. Sub-span Oscillation

4. Longitudinal vibration/movement

Phenomenon of occurrence of Aeolian Vibration.

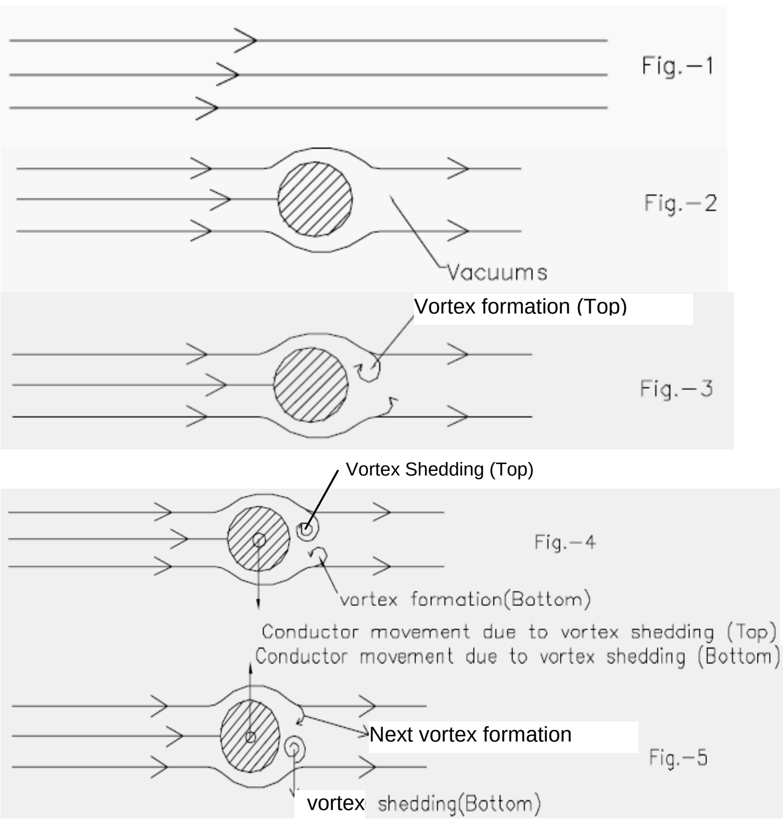


Fig.-1 shows medium speed laminar flow of wind generally prevailing in open plain terrain.

Fig-2 shows flow of wind obstructed by conductor and vacuum creation due to pressure difference on backward surface of conductor.

Fig.-3 shows initiation of vortex formation on top side. This may occur on bottom side first. However it cannot occur on either side i.e. top & bottom together.

Fig.-4 shows shedding of vertex from top side and formation and building up of vortex at bottom. It also shows movement of conductor due to vortex shedding.

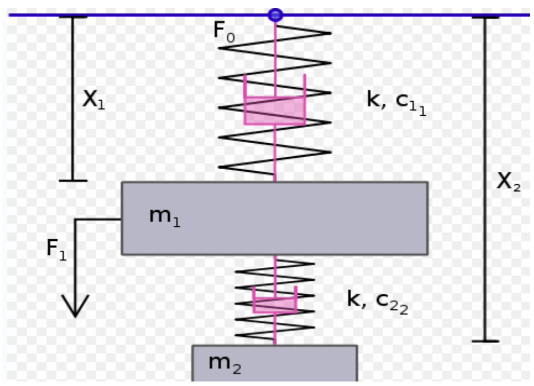
Fig.-5 shows vortex shedding from bottom side and movement of conductor on reverse direction. It also shows repetition of the process.

Thus due to quick repetition of such vortex shedding, the conductor gets induced vertical vibration which is also known as Aeolian Vibration.

Damper Design

The basic principles of Damping found in the Tuned mass damper forms the premise for all design of the dampers used on transmission lines. Tuned mass dampers are used as stabilizers against Harmonic vibration. Its function is to balance the vibration of a system with another comparatively lightweight component so as reduce the impact of the worst-case vibrations on the system. Let us explain the concept of Tuned Mass Dampers in brief.

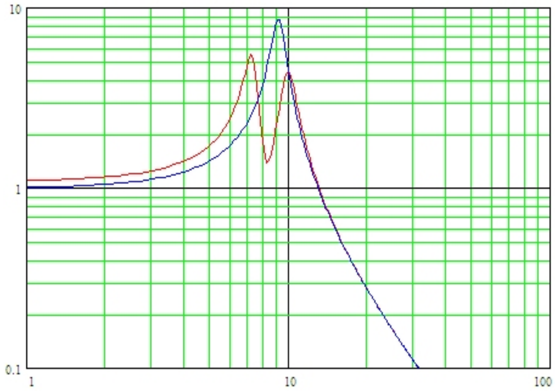
Consider a motor with mass m_1 attached via motor mounts to the ground. The motor vibrates as it operates and the soft motor mounts act as a parallel spring and damper, k_1 and c_1. The force on the motor mounts is F_0; suppose we wish to reduce the maximum force on the motor mounts as the motor operates over a range of speeds.



Let F_1 be the effective force on the motor due to its operation. We will add a smaller mass, m_2, connected to m_1 by a spring and a damper, k_2 and c_2.

The graph shows the effect of a tuned mass damper on a simple spring–mass–damper system, excited by vibrations with an amplitude of one unit of force applied to the main mass, m_1. An important measure of performance is the ratio of the force on the motor mounts to the force vibrating the motor, F_0 / F_1. (We are assuming the system is linear, so if the force on the motor were to double, so would the force on the motor mounts.) The blue line represents the baseline system, with a maximum response of 9 units of force at around 9 units of frequency. The red line shows the effect of adding a tuned mass of 10% of the baseline mass. It has a maximum response of 5.5, at a frequency of 7. as a side effect, it also has a second normal mode and will vibrate somewhat more than the baseline system at frequencies below about 6 and above about 10.

The heights of the two peaks can be adjusted by changing the stiffness of the spring in the tuned mass damper. Changing the damping also changes the height of the peaks, in a complex fashion. The split between the two peaks can be changed by altering the mass of the damper (m_2).

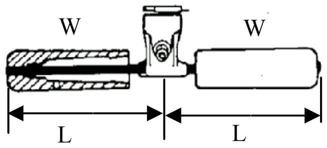


The most common and basic form of dampers was invented by George Stockbridge in 1925 and is called the Stockbridge damper. This was based on the principle of Tuned Mass Dampers. The Stockbridge damper consists of two equal weights rigidly attached to the ends of a double cantilever of the steel cable, which in turn is clamped to the conductor cable by means of a clamp. The damper is essentially a two-degree freedom dynamic with equal inertia members having same mass and moment of inertia and secured rigidly to the opposite ends of the resilient member in the form of stranded steel cable (messenger cable).

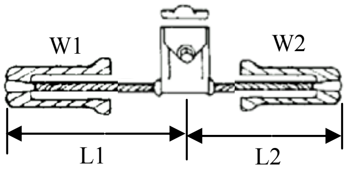
However, the modern dampers are modified to have one of the rigid weights greater than the other and also unequal length on either side. Hence the differential weights and lever arms are used to obtain 4 resonant frequencies. The significance of this is that the damper action is maximum at its resonant frequencies and is less effective as we move away from the resonant frequencies. Having 4 resonant frequencies as opposed to 2 give us a greater damping over the entire spectrum of Aeolian vibration frequencies and also increase the fatigue life of damper itself.

Following are the different kinds of multiple resonant dampers:

1. 2-R Damper



2. 4-R Damper

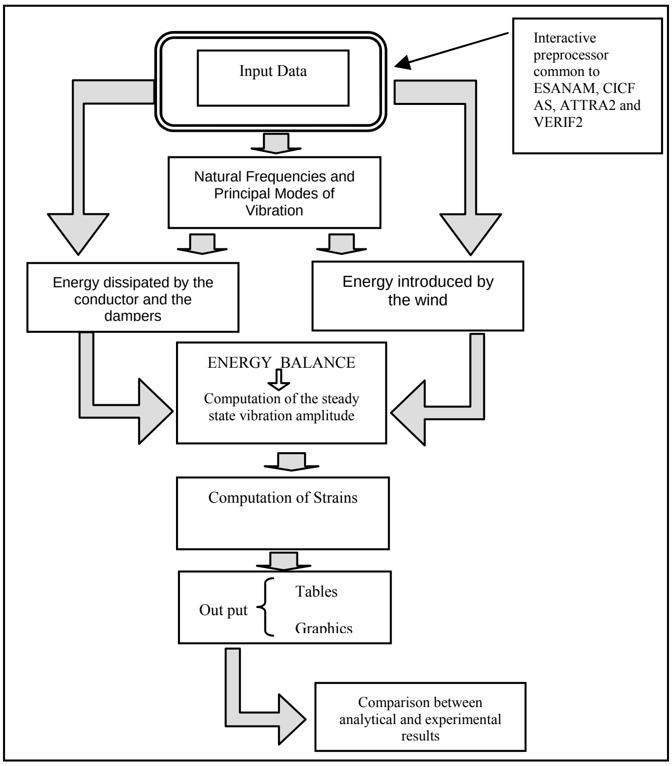


Important features of our design process –

- Should give efficient damping characteristics over full vibration-frequency spectrum – This is achieved by proper design of weights, length and cross-section of the messenger wire and cantilever length of the damper masses.
- Bending strain of entire conductor-damper system – This is achieved by verifying the damper conductor system by laboratory set up and mathematical modeling.
- Optimum damping and quality of clamping – a) Fracture of damper cable should be prevented. b) Avoid bending strain at the installation point.

Testing Mechanism for Vibration Damper

An electro dynamic shaker is used to perform an initial dynamic characteristics test on the damper. It is used with a suitable transducer that digitizes the Force-Displacement Characteristics. The Software provided by the Electro Dynamic Shaker Manufacturer is then used to generate the Mechanical Impedance Curves, which is used extensively in a later process.



Our design are verified by Professor Diana`s Software. We first ascertain the self-damping characteristics. Using this data we design the damper placement over the required frequency spectrum. Using the data obtained, the validation of our damper design is done. The flow chart shows the schematic view of the computer system and the Mechanical system:

Input data to program software:-

1. Conductor data- 2 types of conductors – Metallic and ADSS

ADSS – Overall Diameter (D) , Mass per unit length (m) , The Ultimate Tensile Strength (UTS) and flexural stiffness (EJ) must be assigned.
Metallic – Stranding must be given, the number of wires, diameter and their material. The program automatically computes the conductor overall diameter, the mass per unit length, the ultimate tensile strength and flexural stiffness.

$$\Omega_{0r}=[r\pi/\lambda]^2(T/m)[1+(r\pi/\lambda)^2 EJ/T]$$

This is used to defined the true value of the conductor stiffness $EJ = R_{ed}EJ_{max}$

2. Span End Condition - The two types of constraints for the span extremity are fixed clamp and pivot.

3. Armor Rod – If the armor rods are used at the suspension points, the number of layers must be specified (1 or 2). For any of the layers, the half length (l_a) , number and diameter should be given. If the armor rod total length is l_t , $l_a = (l_t - l_{cl})/2$ which l_{cl} is the suspension clamp length. The material of the armor rods can be steel or aluminum and must be specified.

4. Dead end or suspension clamp – It is possible to introduce data relevant to the type dead end or suspension clamp in both the cases, 2 sets of data are necessary.

- The length of the fitting in meters.
- The moment of inertia with respect to the hinged extremity (kg m^2)

5. Dampers data – If the dampers are installed on the conductor the program needs:
   - The number of dampers installed at one side of the span.
   - The names of the files containing the mechanical impedance of the types of damper used.
   - Damper location
   - The span configuration
   - Value of safety coefficient used to reduce the reduce the energy dissipated by the damper.

For the type of damper to be considered, the mechanical impedance must be realized as a function of frequencies (fig) in files with .amm extension on the computer.

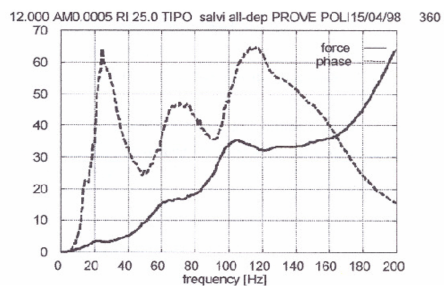


Fig: Mechanical Impedance of a Stockbridge type damper with 4 resonances

6. Types of terrain – The type of terrain affects the turbulence of the wind.

7. Geometric Characteristics of the span – The span length must be assigned.

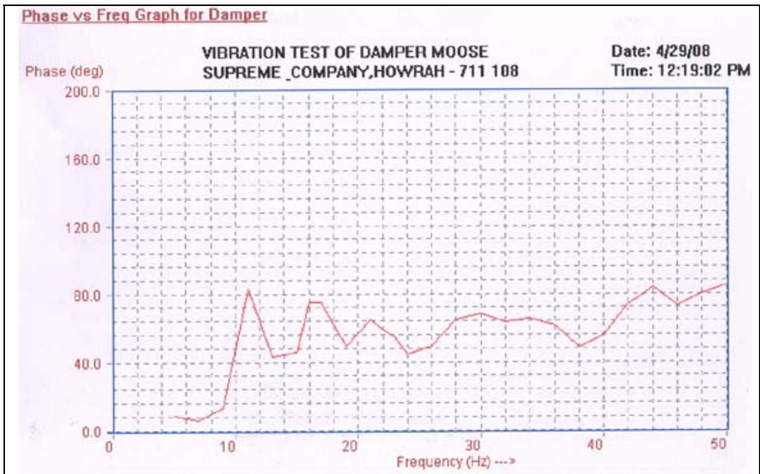
This study along with repeat dynamic characteristics is conducted after completion of 10 + 10 million cycles fatigue test (or as specified by customer) at two higher resonance frequencies. Pre & post fatigue study result are compared to assess reduction/ deterioration of damping efficiency of Vibration Damper.

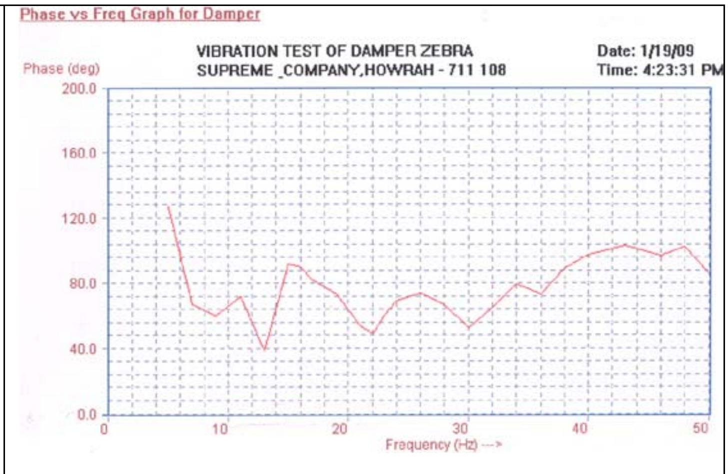
According to IS Standards the following Type Tests are performed –
1. Visual Examination, 2. Verification of Dimensions, 3. Resonance Frequency Test, 4. Fatigue Test, 5. Mass Pull Off Test, 6. Dynamic Characteristics Test, 7. Damping Efficiency Test, 8. Clamp Slip Test, 9. Clamp Bolt Torque Test, 10. Galvanizing/Electroplating Test, 11. Magnetic Power Loss Test, 12. Corona Test, 13. Radio Interference Test

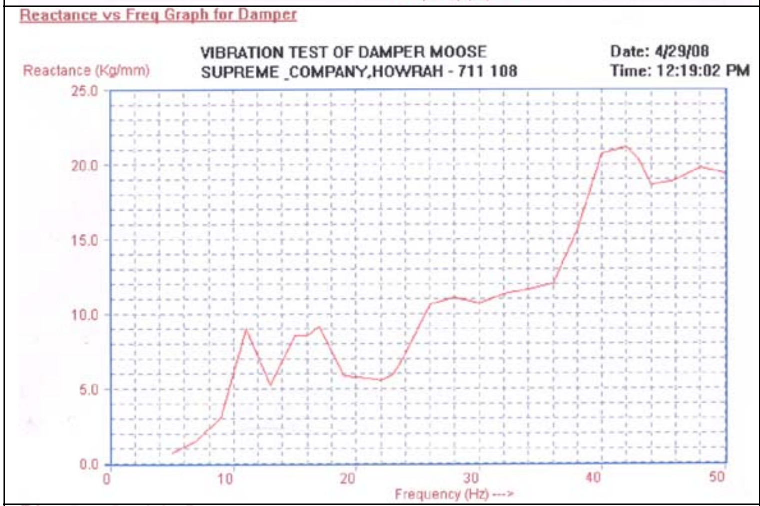
For the routine test , the dampers are subjected to Visual Examination.

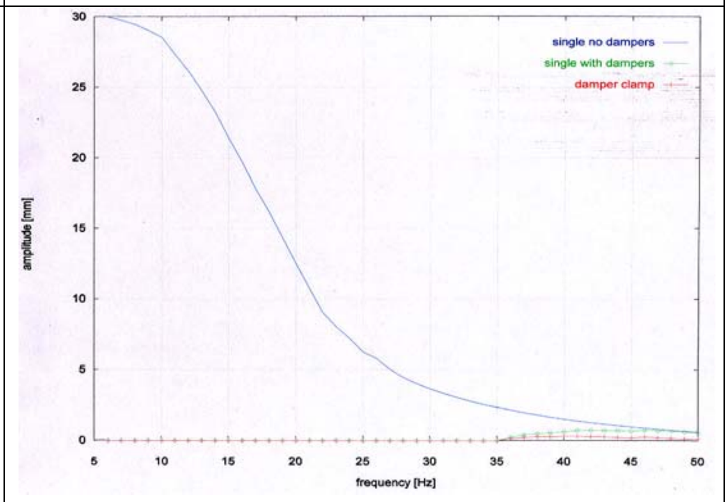
Conforming to IS Standards the following acceptance tests are performed on Vibration Dampers -
1. Visual examination, 2. Verification of dimensions, 3. Resonance frequency test, 4. Fatigue test, 5. Mass pull off test, 6. Galvanizing / electroplating test.

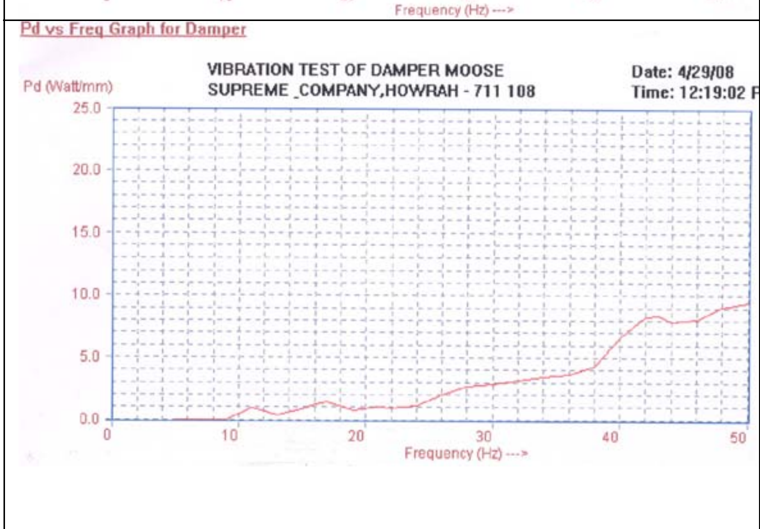
Sample Graphs for Dampers:

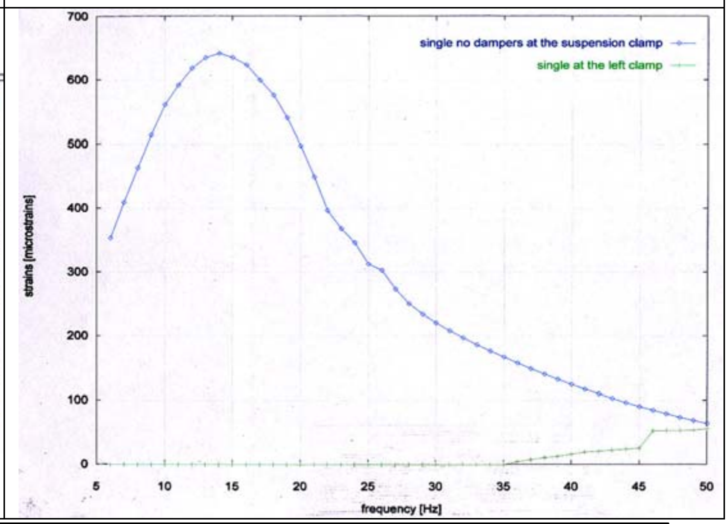












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