ABSTRACT

Design in the fields of aeronautical, mechanical and civil requires lighter, stronger, and more flexible structures. However, light weight structures can be more easily influenced by unnecessary vibrations, which in turn might lead to problems such as fatigue, instability, acoustic disturbances, performance reduction and failure due to resonance. Though the composite structures of lesser weight offer same strength when compared to conventional structures, due to its flexibility in nature tends to exhibit higher level of vibration. Hence, it is essential to control the vibration of the composite structures which would improve the overall efficiency of the system. In order to control the vibration, smart materials such as piezoelectric, shape memory alloys, magneto rheological and electro rheological fluids etc., are used widely because of its smartness. In this present study, flexible cantilever structure is considered as a basic representation model for vibration control owing to the fact that, the cantilever structures are pre-dominantly used in many applications like construction and aerospace. Hence, this investigation is focused on vibration control of structures with the help of smart materials.

This dissertation investigates the development of smart structure for active vibration control. The primary objectives of the present research work is to develop a smart structure for obtaining active vibration control using smart

materials (Piezoelectric and Shape memory alloy) and to develop an Actively Tuned Dynamic Vibration Absorber (ATDVA) using Shape Memory Alloy (SMA) springs. Further, the developed ATDVA was implemented in piping application to control the amplitude of vibration in a pipe line due to variation in hydraulic pulsation frequency.

A detailed literature survey has been carried out to identify the research approach to accomplish the objectives. Attention is mainly focused on SMA based vibration control compared to Lead Zirconium Titanate (PZT). However, the influence of position of PZT along the length of the beam and various control gains are studied over the settling time of aluminium and GFRP beams. The results demonstrate that the position of PZT in high strain region tends to have better control in vibration for the control gain of 20.

SMA has the ability to regain its predetermined shape when heated. In this study, SMA wires of different diameters were used to control the vibration of flexible Glass/Fiber Reinforced Plastics (GFRP) and Aluminum structure. In lieu consideration of the dynamics of SMA, the natural frequency and mode shapes of aluminum and composite cantilever beams are calculated both analytically and numerically. They were also verified experimentally. Natural frequency initially decreases for the beam when the SMA actuator is at martensite phase. Upon further heating of SMA, the natural frequency of the system increases due to the phase transformation from martensite to austenite. From this study, it is evident that the use of SMA will alter the natural frequency of the system. Timing and actuation circuit and displacement feedback controller have been developed to take care of the supply of input current to SMA.

Experiments were carried out on Aluminum and GFRP cantilever structures of different ply orientations $(0°)_6$, $(0°/90°/0°)_s$ and $(60°/0°/30°)_s$. The influence of input current, wire diameters (0.016” & 0.020”), volume fraction of SMA (20% & 40%) and excitation frequencies of 2 Hz, 4 Hz and 6 Hz are studied over the reduction in tip displacement of aluminium and GFRP structures under given test condition. The results obtained demonstrate that the potential of SMA in changing the system natural frequency leads to reduction in tip displacement of cantilever structure. Also, more volume fraction of SMA tends to have more deviation of system natural frequency. Increase in input current to SMA results in more force generated by the wire which provides better reduction in amplitude of vibration. The use of SMA wires of larger diameter (0.020”) greatly suppresses the vibration when compared to the smaller diameter wire (0.016”). When the excitation frequency is away from the natural frequency, it tends to have lesser amplitude of vibration. Hence, this mechanism may not offer more percentage reduction in amplitude of structures. Compared to PZT the cost and voltage required for the actuation of SMA is less.

A dynamic vibration absorber (DVA) can be used as an effective vibration control device by tuning its natural frequency to the frequency of excitation. However, the excitation frequency may not be constant. In order to match with the varying excitation frequency, either the mass or stiffness of the spring has to be varied. Since it is not possible to change the mass dynamically, an attempt has been made to change the stiffness of the spring dynamically. Also, this study employs the shape memory alloy spring based ATDVA. The selected SMA spring is calibrated to find out the variation in temperature for the applied current in order to develop an effective control system. From the experimental results, it is evident that the SMA-based ATDVA is more effective in damping out the vibration for wider excitation frequencies.

The developed ATDVA is implemented in a piping application to control the vibration due to hydraulic pulsation frequency. Though the vibration in the pipelines may be caused by various factors, the main factor is the hydraulic pulsation, when the impeller continuously transmits tiny pockets of water into the pipeline, which is the result of operating condition of the pump. The excitation frequency (hydraulic pulsation) of this case is calculated analytically as 336Hz. However in the experimental results, the peak value is found to vary between 336 and 339 Hz. For the varying frequencies, the conventional absorber has to be redesigned and this is a cumbersome task. From the experiments carried out with ATDVA, it is found that around 55-65% reduction in amplitude of vibration is possible for the selected frequency range.