Abstract

Pseudoelastic property displayed by shape memory alloy (SMA) is widely used in structural vibration control. The irreversibility in stress-induced phase transformation (from austenite to martensite and vice-versa) leads to energy dissipation. If a SMA element is used as a member of a vibrating system, the dissipation of energy helps to damp out vibration. In the present work, a rigid mass connected to a massless SMA bar is considered as a simple vibrating system where the axially deforming bar acts as a passive element. The vibrational characteristics of the system are studied under harmonic excitation, either due to an external force or due to the constrained motion. The restraining force on the vibrating mass has been calculated using one dimensional coupled thermomechanical model developed by Lagoudas and coworkers. The model, developed within the macroscopic framework, employs stress, temperature, and martensite volume fraction as the state variables. The use of stress, rather than strain as an independent variable, presents a difficulty in formulating the equations of motion. This problem has been solved by casting the equations in a novel state-space form. The heat generated during vibration leads to the temperature rise of the bar unless an arrangement is made to keep it constant. In the latter case, temperature appears as a fixed parameter while in the former case, the temperature is taken as an additional state variable. The governing equations have been solved numerically to get the response under various operating conditions. The same has been attempted by an analytical method. To this end, first equivalent linearised stiffness and damping of a SMA bar operating in isothermal and non-isothermal conditions are evaluated. The linearised stiffness and damping of SMA bar are employed to analytically analyse the steady-state amplitude of pseudoelastic oscillators subjected to harmonic forcing or motion excitation. Frequency response curves have been generated in terms of maximum displacement amplitude for the oscillators at different excitation amplitudes. The nonlinear stiffness and damping characteristics of the SMA bar lead to various interesting jump phenomena in the frequency response behaviour. The efficacy of the SMA to control vibration has been evaluated by studying, again numerically two important characteristics, namely, the force and motion transmissibilities. Although these are defined in the literature for linear systems, new measures are introduced to suit the nonlinear system, such as the one considered in this thesis. The force and motion transmissibility characteristics of pseudoelastic oscillator subjected to harmonic loading are evaluated at different environmental conditions and levels of excitation amplitude. The effect of temperature rise during operation has also been studied.

Keywords: Shape memory alloy, Pseudoelasticity, Complex stiffness, Motion transmissibility, Force transmissibility, Jump phenomenon, Isothermal, Non-isothermal.