Statics and Dynamics of Composite Structures with Embedded Shape Memory Alloys

A new class of modern smart materials such as piezoelectric polymers and ceramics, electrorheological fluids, optical fibers and shape memory alloys have a great number of possible applications in many industrial and engineering fields. This number grows constantly encouraging scientists and engineers to study and analyze the behavior of the materials, range and ways of their best use.

Shape memory alloy reinforced composites are an extremely versatile class of materials. Shape memory alloys are characterized by: large internal forces, unique ability of changing its material properties, wide range of operational temperature, excellent damping properties and high durability. Mechanical and physical properties of SMA strongly depend on temperature and initial stresses. Changes in temperature and initial stresses involve changes in the volume fraction of martensite in the alloys. During the martensite transformation recovery stresses appear. These recovery stresses are not only a function of alloys temperature but also depend on initial strains. Using shape memory alloys as fibre reinforcement gives structures numerous adaptive capabilities. One of them is the controlling of motion and the vibration of structures.

In order to model accurately the behavior of composite structures with embedded shape memory alloy components three literature models have been carefully examined. These models have been studied according to their abilities to predict properly superelastic and shape memory effects associated with the thermomechanical behavior of shape memory alloys and special attention has been paid to the set of state variables chosen for each model (Tanaka, Liang & Rogers, Brinson).

The lecture illustrates stress-strain relationships for composite structures with embedded SMA fibres and their influence upon certain changes in natural frequencies and thermal buckling of selected composite structures. Governing equations based on the finite element method are formulated for beams, plates, and shells. Active frequency controlling can be used, for example, to avoid resonances in composite structures such as shafts, blades, aircraft wings, etc. The finite element analysis results are compared to those obtained from an analytical continuum solution.

The results of calculations demonstrate the potential effectiveness of SMA fiber-reinforcement in composite structural elements in the process of controlling the vibration. The effect of SMA fibers activation on the amplitude of vibration normalized with respect to the amplitude of the uncontrolled vibration can also be analyzed.

It can be clearly observed that the activation process of SMA wires involves an increase in the natural bending frequencies. This effect rises when both the temperature and initial strains are higher.