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Review on Modal analysis of Shape Memory Alloy Beams

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A B S T R A C T

Modal analysis is the process of determining the inherent dynamic characteristics of a system in forms of natural frequencies, damping factors and mode shapes and using them to formulate a mathematical model for its dynamic behaviour. The modal analysis of shape memory alloy beam in simply supported configurations is our main moto in this paper. The beam deflections and vibration frequencies will be calculated using finite element techniques.

Keywords: Ansys, Composite Materials, Modal Analysis, Beam, Shape Memory Alloy

1. Introduction

Shape memory refers to the ability of certain materials to "remember" a shape, even after rather severe deformations once deformed at low temperatures, these materials will stay deformed until heated, where upon they will spontaneously return to their original, pre deformation shape. Smart materials which are among the advanced materials have unique characteristics of actuation and sensing capabilities, like load, electricity or heating. These materials can be embedded into any suitable matrix material to make the resulting composite smart. Shape Memory Alloy (SMA) is found to be more useful among the various classes of smart materials. Composites of embedded SMA wire/sheet in appropriate flexible resin systems has found ample potential applications in Aerospace, Automobile, Medical and other similar areas. SMAs are also capable of actuating in a fully three-dimensional manner, allowing the fabrication of actuation components which can extend, bend, twist, in isolation or combination; and can be used in various configurations and shapes such as helical springs, torsion springs, straight wires, cantilever strips, and torsion tubes. SMAs can provide a highly innovative approach to solve a wide range of engineering problems. SMA is employed for actuation and pseudo elasticity for vibration isolation and dampening. For example, the two unique pseudo elastic behaviors of SMA. Shape Memory alloys (SMA), due to their pseudo elastic and good damping properties, are increasingly using in structures. The common two types of SMA are copper-aluminum and nickel-titanium (Nitinol) alloys. NITINOL SMA is most preferred in most applications due to stability.

2. Literature Review

1. Ebin Justin S1, Ankit Kumar Mishra [1] presented paper on Structural Analysis of Simply Supported Composite Beam Exposed to Transient Loading. In their study Structural analysis has been done on composite beams with different dimensions to find deflection and strain on transient loading. As the models were simple geometry two composite beams with dimensions 150*51; 250*51 mm are designed through Ansys Design Modeler. The simulations were performed in Ansys Mechanical. Force, Displacement and fixed support are the boundary conditions given for the analysis. A 3mm element size is given to generate the mesh. In this analysis Force, strain and directional deformation are considered major parameters. The simulations were done by considering ten different forces for three-point loading and sixteen different forces for four-point loading. Normal elastic strain and directional deformation (deflection) are obtained from the analysis of different forces applied. The graph is plotted for the values obtained at different time steps during transient loading.

2. Alaa El-Sisi, Fahad Alsharari etc. [2] has done investigation on topic "Efficient beam element model for analysis of composite beam with partial shear connectivity". In this investigation a two-node beam element formulation with eight degrees of freedom was developed and implemented into MATLAB to simulate the nonlinear behavior of the composite. The beam element includes the reinforced concrete slab, the concrete reinforcement, the steel beam, and the shear connectors. One dimension-softening model was used to simulate the concrete, the bilinear isotropic plastic model was used to simulate the steel, and a multi-linear spring was used to simulate the partial shear connectivity. Experimental results were used to validate the numerical model, which was able to closely predict the experimental response by a 2% difference. The model was able to simulate several material nonlinearities such as the plasticity of the steel beam and cracking and crushing of concrete slab. A parametric study was performed to investigate the effects of strength of shear connector, concrete slab thickness, steel beam depth, and the concrete compressive strength on the overall response of steel–concrete composite beams. It was found that the variation in shear connector strength significantly

affects the response of the composite beams. In addition, the composite beam stiffness and strength increased with the increase of the steel beam depth, significantly.

3. Zhixiang Rao, Xiaoyuan Wang etc. [3] has presented their work on Design methodology of NiTi Shape Memory alloy beam actuator. In this study, an in-depth investigationwas conducted into the Ni50Ti50 (at%) SMA beam actuator from the perspective of heat treatment, training, numerical simulation for developing a comprehensive and novel design methodology. The proper heat treatment conditions that result in the relatively high actuation performance for the Ni50Ti50 SMA beam were determined. The dependence of the thermomechanical behaviour evolution on the training load was established. Moreover, a numerical analysis method for the SMA beam actuator based on a 3-D constitutive model with tension-compression asymmetry considered was detailed, followed by the calibration of material parameters. A forward design method for the SMA beam actuator was proposed with the shape and actuation performance evolution during training under various training loads fully considered in the design process. The proposed design method was applied for a design case and the accuracy of the design results demonstrated its feasibility.

4. Qianlong Zhang, Hongfei Zhu etc. [4] has proposed on the nonlinear analysis of pre-Strained shape memory alloy beams. They presented a theoretical and numerical investigation of the transverse dynamic response of monolithic Shape Memory Alloy (SMA) beams under the effect of axial pre-strains. The SMA beam is taken as benchmark structure to evaluate the effect of (axial) pre-strain on either the free or the forced dynamics. The combination of the static stress, produced by the preloading conditions, with the dynamic stress, associated with the vibratory response, affects the occurrence of the stress-induced SMA phase transformation hence providing a mechanism to passively tune the dynamic response. Particular attention is given to the effect that different pre-strain levels have on the overall ability to dissipate mechanical energy, that is on the effective damping. The numerical model of the SMA beam accounts for both material and geometric nonlinear behaviours. The nonlinear material behaviour is due to the SMA phase-transformation and it is modelled via the one-dimensional improved Brinson's model (including tension–compression asymmetry), while the geometric nonlinear behaviour is due to large displacements occurring during the phase transformation and it is accounted for via von Kármán assumptions. The resulting model is solved numerically via the finite element method and used to evaluate both the free and the forced response of the beam. The free response analysis suggests the existence of optimal pre-strain levels to achieve maximum damping capacity, while the forced response highlights the occurrence of nonlinear dynamic features, such as bifurcation. In both cases, it is found that the level of pre-strain can significantly affect the dynamic response as well as the effective damping. The results presented in this work provide useful guidelines to understand the dynamics of continuous SMA structures under pre-strain and the ability to tune either their resulting dynamics or dissipation properties.

5. Alireza Tabrizikahou, Mieczyslaw kuczma etc. [5] has presented Application and modelling of Shape-Memory Alloys for structural vibration Control One of the most essential components of structural design for civil engineers is to build a system that is resistant to environmental conditions such as harsh chemical environments, and catastrophic disasters like earthquakes and hurricanes. Under these circumstances and disturbances, conventional building materials such as steel and concrete may demonstrate inadequate performance in the form of corrosion, deterioration, oxidizing, etc. Shape Memory Alloys (SMAs) are novel metals with distinct features and desirable potential to overcome the inadequacies of existing construction materials and enable the structure to tolerate disturbances more efficiently. Shape Memory Effect (SME) and Pseudoelasticity (PE) have been the most attractive characteristics that scientists have focused on among the various features that SMAs exhibit. The SME enables the material to retain its original shape after severe deformation, whereas the PE behaviour of SMAs provides a wide range of deformation while mitigating a substantial amount of susceptible stresses. These behaviours are the consequence of the phase transformation between austenite and martensite. Many investigations on the modelling and application of SMAs in structural systems to endure applied dynamic loadings in the form of active, passive, and hybrid vibration control systems have been undertaken. The focus of this paper is to present an overview of the SMA-based applications and most frequently employed constitutive modelling, as well as their limits in structural vibration control and seismic isolation devices.

6. Quinan lei, Peng Wang etc. [6] has presented their Study on Mechanical properties of Simply Supported composite beams considering Creep and Slip. In order to further study the mechanical properties of steel–concrete composite beams under creep–sliding coupling, in this study, based on the energy variational method principle, the energy equation of a composite beam considering creep and slip coupling is established. The second-order differential equation of the axial force of steel–concrete composite beams is derived by introducing basic assumptions. The calculation formulas for the axial force, deflection, and slip of simply-supported composite beams under different loads are obtained using different boundary conditions. Then, the creep effect of composite beams is simulated using the creep criterion in the ANSYS finite element software when the concrete material parameters change with time. The results show that a simply-supported composite beam considering both slip and creep will have a significant effect on the structure; the more strongly the studs constrain the concrete slab, the greater the adverse effect of concrete creep on the combined beam. The formula derived in this paper is consistent with the numerical simulation solution and is suitable for different creep and slip conditions. The research results can provide a theoretical basis for the calculation of the axial force, deflection, and slip of combined beams under uniform and concentrated loads in practical engineering considering slip and creep.

7. Jun Wang, Bin Huang etc. [7] has presented their work on actuation performance of machined helical springs from NiTi shape memory alloy. In this paper Machined helical springs were designed and fabricated from NiTi shape memory alloy tube stock by cutting helical slots to make the coils, which provided them with high design flexibility and actuation potential. The springs were then subjected to isothermal tensile testing at temperatures of 20 ◦C and 80 ◦C, the experimental data showed that they could generate more than 50% actuation stroke at the applied force of 300 N. A material model was introduced to describe the thermally-induced actuation behaviour of the machined NiTi spring. Finite element

simulation of the springs was carried out to investigate the effects of geometries and applied loads on the actuation performance. With increasing applied load, the actuation stroke and transformation temperature increased as well, indicating more actuation potential at high loads. The actuation stroke was positively correlated to the outer diameter and the cross-sectional aspect ratio, negatively correlated to the cross-sectional area, and independent of the coil pitch. A variable-sweep wing actuated by two antagonistic machined springs was designed and numerically analysed, the actuator could generate a steady cyclic motion up to 40 mm and allowed the swept-back angle of the wings to be continuously varied from zero to 90 degrees.

8. N. Bykiv, P. Yasniy etc. [8] has done Finite Element Analysis of reinforced-concrete beam with shape memory alloy under the bending. The paper deals with strengthening of the reinforced concrete beam by shape memory alloy at the place of maximum loading and deformation. A structural analysis is performed using FEM to study the behaviour of the beam reinforced by steel and shape memory alloys under 3- and 4-point bending. The elasticity of the reinforced concrete beam with NiTi rods slightly increase and depends on loading type. It was revealed, that under the bending in the beam reinforced by shape memory alloy the residual deflection decreases in comparison with traditional reinforcement.

9. N.J. Sai Sujith, Anudeep Krishna and Basavaraj Noolvi [9] has done investigation of dynamic characteristics of Smart Composite Cantilever beam. This work is focused on the static studies on Smart active composites cantilever beams (SACCB) obtained by reinforcing shape memory alloy wires in a polymer matrix. Homogenization is carried out for the composite using the rule of mixtures to obtain effective material properties. Analytical modelling is carried out for SACCB to determine the beam tip deflection. SACCB specimen is fabricated using hand layup process. A suitable die is prepared so that it provides the required pretension in the SAM wires reinforced in SACCB. Experimental studies are conducted on the SACCB in the static cantilever beam condition. A comparison of the analytical and experimental results is presented.

10. Basavaraj Noolvi, Shanmukha Nagraj [10] has done modal analysis of Smart Composite Cantilever Beams. This work presents modal analysis of a Smart hybrid composite beam (SHCB) in cantilever configuration, constituted of LY551 resin by enclosed shape memory alloy (SMA) wires amidst layers of 0/90 glass fibres. The overall properties of the SHCB are estimated using method of mixtures, and the beam tip deflection and frequencies are first calculated analytically. Finite element studies are conducted to determine the beam tip deflections and frequencies of vibration. Comparative study of the analytical, and FEA results has been presented.

3.Methodology:

3.1 Beam Model

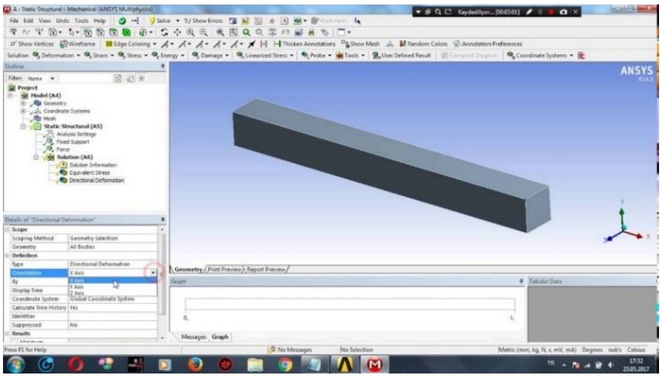

Fig. 1.1 Beam model

3.2 Mesh

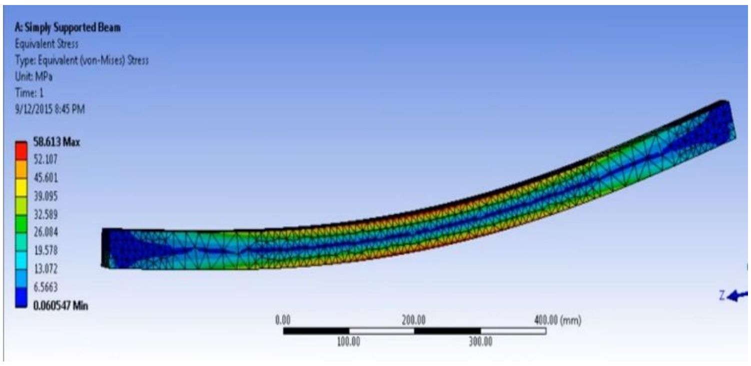

Fig. 1.2 Meshing

3.3 Static Structural Analysis

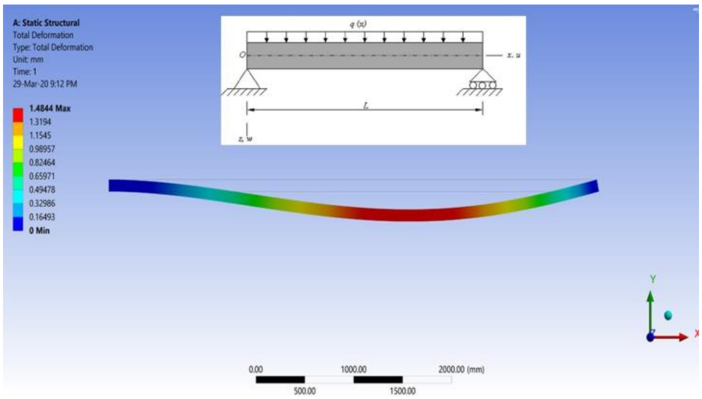

Fig. 1.3 - Static Structural Analysis of Simply Supported Beam.

3.4 Mesh

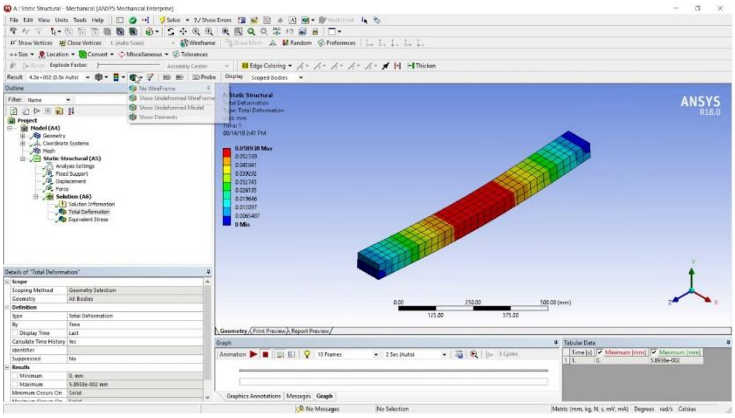

Fig. 1.4 – Mesh Beam

3.5 Modal Analysis

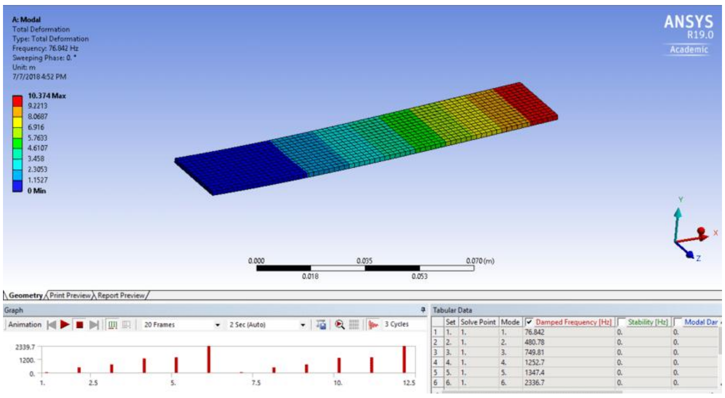

Fig. 1.5 - Modal Analysis of Beam.

4. Dynamic Analysis Result

Analysis type	Beam tip deflection in mm
Analytical	0.064
FEA	0.062

5. Conclusion:

We have successfully reviewed papers related to our topic Shape Memory Alloy beams. We have seen that there has been works on Shape memory alloy structures, however there has no work on Shape Memory alloy beam in simply supported configurations. So, our aim is to do Modal analysis of Shape Memory Alloy beam in Simply Supported configurations with center point load. Also, we will change load position and will find frequencies and mode shapes.

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