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Dynamics Of Multi layered Composite Shell With Shape Memory Alloys

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Abstract: The use of different composite materials has been continuously growing in recent years. Although many applications for composite materials have been identified. Extensive research is still being carried out in order to expand this field. New materials and technologies have been researched. One such new application is the integration of shape memory materials within composite materials.

In this study certain aspects of the dynamic behavior of a multilayered composite shell with shape memory alloy (SMA) wires have been investigated. The influence of SMA wires, the orientation and the thickness to diameter ratio and different boundary conditions, on changes in critical load, the natural frequencies and modes of vibration of the shell have been studied and discussed in the present study. The results presented are obtained by the use of finite element method. The analysis both static and modal has been carried out using ANSYS 12.0.

The shape memory alloys possess the inherent ability to change their material properties in particularly their young's modulus, damping capacity as well as great capacity for the generation of large internal forces. Integrating SMA's within composite material structures potentially allow the active control of certain static and dynamic behaviour of the integrated structures. Precise tuning of SMA components enables the control of certain static and dynamic characteristics of composite material structures, notably deflections and shape, natural frequencies and modes of vibrations.

SMA components embedded into or bonded to composite material structures can be utilized in two different ways. They are Active Property Tuning Method and Active Strain energy Tuning Method. These techniques induces a special property in SMA components integrated with appropriate composite material structures leads to high generation of high recovery stresses.

I. INTRODUCTION

A Composite Material can be defined as a combination of two or more materials that results in better properties than those of the individual components used alone. In contrast to metallic alloys, each material retains its separate chemical, physical, and mechanical properties. The two constituents are reinforcement and a matrix. The main advantages of composite materials are their high strength and stiffness, combined with low density, when compared with bulk materials, allowing for a weight reduction in the finished part.

The reinforcing phase provides the strength and stiffness. In most cases, the reinforcement is harder, stronger, and stiffer than the matrix. The reinforcement is usually a fiber or a particulate. Particulate composites have dimensions that are approximately equal in all directions. They may be spherical, platelets, or any other regular or irregular geometry. Particulate composites tend to be much weaker and less stiff than continuous-fiber composites, but they are usually much less expensive. Particulate reinforced composites usually contain less reinforcement (up to 40 to 50 volume percent) due to processing difficulties and brittleness.

A fiber has a length that is much greater than its diameter. The length-to-diameter (l/d) ratio is known as the *aspect ratio* and can vary greatly. Continuous fibers have long aspect ratios, while discontinuous fibers have short aspect ratios. Continuous-fiber composites normally have a preferred orientation, while discontinuous fibers generally have a random orientation. Examples of continuous reinforcements include unidirectional, woven cloth and helical winding (Fig.1.1a), while examples of discontinuous reinforcements are chopped fibers and random mat (Fig. 1.1b). Continuous-fiber composites are often made into laminates by stacking single Sheets of continuous fibers in different orientations to obtain the desired strength and stiffness properties with fiber volumes as high as 60 to 70 percent. Fibers produce high-strength composites because of their small diameter; they contain far fewer defects (normally surface defects) compared to the material produced in bulk. As a general rule, the smaller the diameter of the fiber, the higher its strength, but often the cost increases as the diameter becomes smaller. In addition, smaller-diameter high-strength fibers have greater flexibility and are more amenable to fabrication processes such as weaving or forming over radii. Typical fibers include glass, aramid, and carbon, which may be continuous or discontinuous.

The continuous phase is the matrix, which is a polymer, metal, or ceramic. Polymers have low strength and stiffness, metals have intermediate strength and stiffness but high ductility, and ceramics have high strength and stiffness but are brittle. The matrix (continuous phase) performs several critical functions, including maintaining the fibers in the proper orientation and spacing and protecting them from abrasion and the environment. In polymer and metal matrix composites that form a strong bond between the fiber and the matrix, the matrix transmits loads from the matrix to the fibers through shear loading at the interface. In ceramic matrix composites, the objective is often to increase the toughness rather than the strength and stiffness; therefore, a low interfacial strength bond is desirable.

2. REINFORCEMENT TYPES

The type and quantity of the reinforcement determine the final properties. Figure 1.2 shows that the highest strength and modulus are obtained with continuous-fiber composites. There is a practical limit of about 70 volume percent reinforcement that can be added to form a composite. At higher percentages, there is too little matrix to support the fibers effectively. The theoretical strength of discontinuous-fiber Composites can approach that of continuous-fiber composites if their aspect ratios are great enough and they are aligned, but it is difficult in practice to maintain good alignment with discontinuous fibers. Discontinuous-fiber composites are normally somewhat random in alignment, which dramatically reduces their strength and modulus. How- ever, discontinuous-fiber composites are generally much less costly than continuous-fiber composites. Therefore, continuous-fiber composites are used where higher strength and stiffness are required (but at a higher cost), and discontinuous-fiber composites are used where cost is the main driver and strength and stiffness are less important.

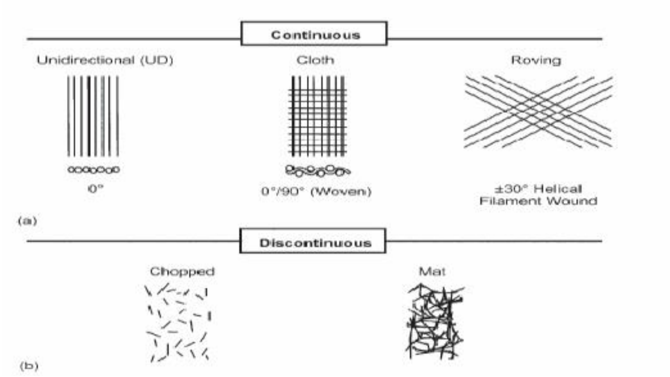


Fig. 2.1 Typical reinforcement types

Both the reinforcement type and the matrix affect processing. The major processing routes for polymer matrix composites are shown in Fig.. Two types of polymer matrices are shown: thermosets and thermoplastics. A thermoset starts as a low-viscosity resin that reacts and cures during processing, forming an intractable solid. A thermoplastic is a high-viscosity resin that is processed by heating it above its melting temperature. Because a thermoset resin sets up and cures during processing, it cannot be reprocessed by reheating. By comparison, a thermoplastic can be reheated above its melting temperature for additional processing. There are processes for both classes of resins that are more amenable to discontinuous fibers and others that are more amenable to continuous fibers. In general, because metal and ceramic matrix composites require very high temperatures and sometimes high pressures for processing, they are normally much more expensive than polymer matrix composites. However, they have much better thermal stability, a requirement in applications where the composite is exposed to high temperatures.

This book will deal with both continuous and discontinuous polymer, metal, and ceramic matrix

2.1 Isotropic, anisotropic, and Orthotropic Materials

Materials can be classified as either isotropic or anisotropic. Isotropic materials have the same material properties in all directions, and normal loads create only normal strains. By comparison, anisotropic materials have different material properties in all directions at a point in the body. There are no material planes of symmetry, and normal loads create both normal strains and shear strains. A material is isotropic if the properties are independent of direction within the material.

For example, consider the element of an isotropic material shown in Fig. 2.2. If the material is loaded along its 0°, 45°, and 90° directions, the modulus of elasticity (E) is the same in each direction ($E_{0°} = E_{45°} = E_{90°}$). However, if the material is anisotropic (for example, the composite ply shown in Fig. 2.3**)**, it has properties that vary with direction within the material. In this example, the module are different in each direction ($E_{0°} \neq E_{45°} \neq E_{90°}$). While the modulus of elasticity is used in the example, the same dependence on direction can occur for other material properties, such as ultimate strength, poisson's ratio, and thermal expansion coefficient.

Bulk materials, such as metals and polymers, are normally treated as isotropic materials, while composites are treated as anisotropic. However, even bulk materials such as metals can become anisotropic—for example, if they are highly cold worked to produce grain alignment in a certain direction.

Consider the unidirectional fiber-reinforced composite ply (also known as a *lamina*) shown in Fig. 2.4. The coordinate system used to describe the ply is labeled the *1-2-3 axes*. In this case, the 1-axis is defined to be parallel to the fibers (0°), the 2-axis is defined to lie within the plane of the plate and is perpendicular to the fibers (90°),and the 3-axis is defined to be normal.

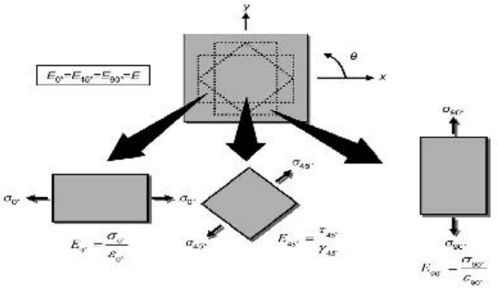


Fig. 2.2 Element of isotropic material under stress

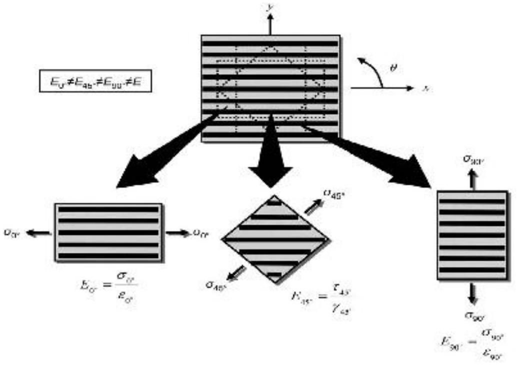


Fig. 2.3 Element of composite ply material under stress

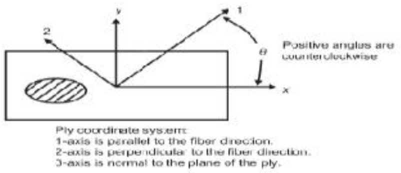


Fig2.4 Ply angle definition

3. LAMINATES

When there is a single ply or a lay-up in which all of the layers or plies are stacked in the same orientation, the lay-up is called a *lamina*. When the plies are stacked at various angles, the lay-up is called a *laminate*. Continuous-fiber composites are normally laminated materials (Fig. 3.1) in which the individual layers, plies, or laminae are oriented in directions that will enhance the strength in the primary load direction. Unidirectional (0°) laminae are extremely strong and stiff in the 0° direction. However, they are very weak in the 90° direction because the load must be carried by the much weaker polymeric matrix. While a high-strength fiber can have a tensile strength of 500 ksi (3500 Mpa) or more, a typical polymeric matrix normally has a tensile strength of only 5 to 10 ksi (35 to 70 Mpa) (Fig. 3.2). The longitudinal tension and compression loads are carried by the fibers, while the matrix distributes the loads between the fibers in tension and stabilizes the fibers and prevents them from buckling in compression. The matrix is also the primary load carrier for inter-laminar shear (i.e., shear between the layers) and transverse (90°) tension. The relative roles of the fiber and the matrix in determining mechanical properties

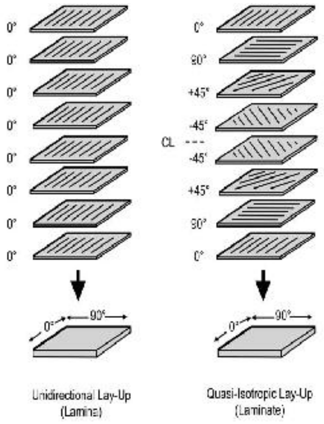


Fig. 3.1 Lamina and laminate lay-ups

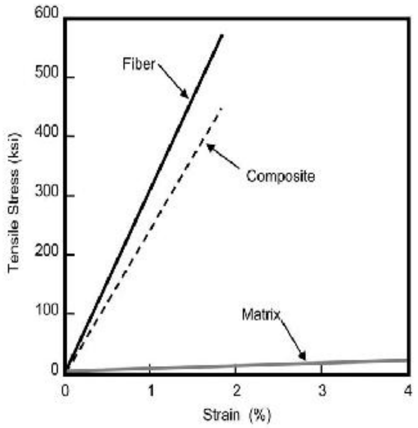


Fig. 3.2 Comparison of tensile properties of fiber, matrix, and composite

Because the fibre orientation directly impacts mechanical properties, it seems logical to orient as many of the layers as possible in the main load-carrying direction. While this approach may work for some structures, it is usually necessary to balance the load-carrying capability in a number of different directions, such as the 0°, +45°, –45°, and 90° directions. Figure 3.3 shows a photomicrograph of a cross-plied continuous carbon fiber/epoxy laminate. A balanced laminate having equal numbers of plies in the 0°, +45°, –45°, and 90° degrees directions is called a *quasi-isotropic laminate*, because it carries equal loads in all four directions

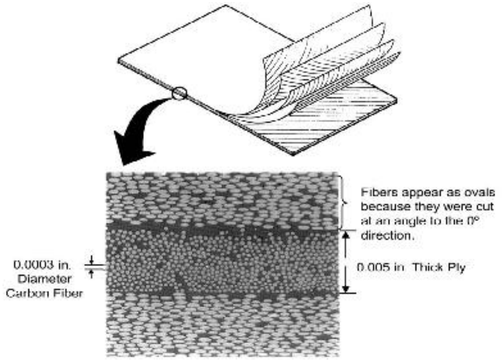


Fig. 3.3 Cross section of a cross-plied carbon/epoxy laminates

4. SHAPE MEMORY ALLOYS

Certain metallic materials will, after an apparent plastic deformation. Return to their original shape when heated the same materials in a certain temperature range, can be strained up to approx. 10% and still will return to their original shape when unloaded. These unusual effects are called thermal shape memory and super elasticity (elastic shape memory) respectively [I] . Both effects depend on the occurrence of a specific type of phase change known as thermo elastic transformation. Shape memory and supereJastic alloys respond to temperature changes and mechanical stresses in nonconventional and highly amazing ways. They are, therefore, sometimes called "smart materials". The shape memory effect can be used to generate motion and/or force, while super elasticity allows energy storage. Both effects have fascinated scientists and engineers for almost three decades. Drawing them to show in conferences and seminars in great numbers. However, very few developments made it to the market, and can be considered economic successes. Recent successes come mainly from medical applications utilizing the super elasticity and biocompatibility

4.1 SHAPE MEMORY EFFECT

"Shape Memory" describes the effect of restoring the original shape of a plastically deformed sample by heating it. This phenomenon results from a crystalline phase change known as "thermo elastic martensitic transformation". At temperatures below the transformation temperature shape memory alloys are martensitic, in this condition. Their microstructure is characterized by "self-accommodating twins", The manensite is soft and can be deformed quite easily by de-twinning. Heating above the transformation temperature recovers the original shape and converts the material to its high strength austenitic condition.

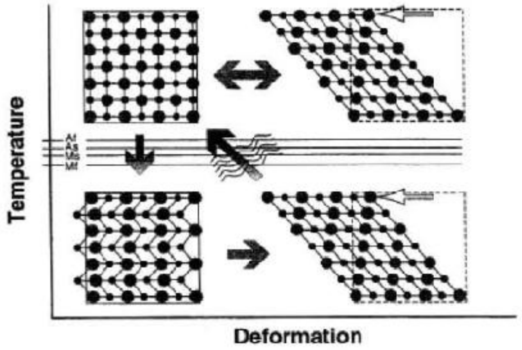
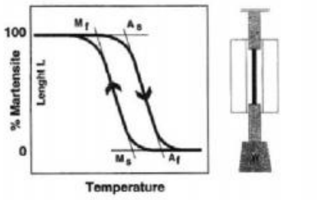


Fig. 4.1: Schematic representation of the shape memory effect and super elasticity

The transformation from austenite to martensite and the reverse transformation from martensite to austenite do not take place at the same temperature. A plot of the volume fraction of martensite, or more practically the length of a wire loaded with a constant weight as a function of temperature provides a curve of the type shown schematically in Figure4.2. The complete transformation cycle is characterized by the following temperatures: austenite start temperature (As). Austenite finishes temperature (Af). Manensite start temperature (Ms) and manensite finish temperature (Mf).

If a stress is applied to a shape memory alloy in the temperature range between Af and a maximum temperature Md, martensite can be stress-induced. Less energy is needed to stress-induce and deform martensite than to deform the austenite by conventional mechanisms. Up to 10% strain can be accommodated by this process (single crystals of specific alloys can show as much as 25% pseudo elastic strain in cenain directions). As austenite is the thermo dynamically stable phase at this temperature under no-load conditions, the material springs back into its original shape when the stress is no longer applied. This extraordinary elasticity is also called pseudo elasticity or transformational super elasticity.

It becomes increasingly difficult to stress-induce martensite at increasing temperatures above Af. Eventually, it is easier to deform the material by conventional mechanisms than by inducing and deforming martensite. The temperature at which martensite is no longer stress-induced is called Md. above Md, the alloys are defamed like ordinary materials. Thus, super elasticity is only observed over a narrow temperature range.



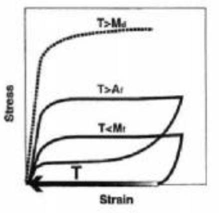


Fig. 4.2 (left): Schematic representation of the hysteresis loop
Fig.4. 3 (right): Stress/strain curves at different temperatures

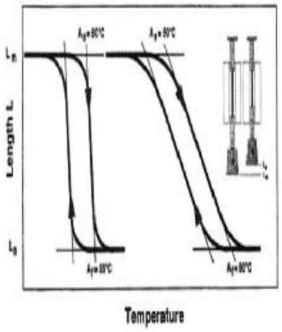
The design of shape memory components, e.g. fasteners or actuators, is based on the distinctly different stress/strain curves of the martensile and austenite, and their temperature dependence. Figure 4.3 shows tensile curves of a Ni-Ti alloy at various temperatures. While the austenitic curve (T>Md) looks like that of a "nonnal" material, the martensitic one (T <Mf) is quite unusual. On exceeding a first yield point, several percent strain can be accumulated with only little stress increase. After that, stress increases rapidly with further deformation. The deformation in the "plateau region" can be recovered thermally. Deformation exceeding a second yield point cannot be recovered. The material is then plastically deformed in a conventional way. At temperatures T>Af, again, a plateau is observed upon loading. In this case, it is caused by stress induced martensite. Upon unloading the material transforms back into austenite at a lower stress (unloading plateau). With increasing temperature, both loading and unloading plateau stress increase linearly [2].

4.2 SHAPE MEMORY ALLOYS

The shape memory effect as the result of a manensitic transformation has been known since the mid 1950's, when the effect was discovered in copper base alloys. In the early sixties researchers at the Naval Ordnance Laboratory found the shape memory effect in Ni-Ti alloys (Nitinol- Ni-Ti Naval Ordnance Lab). Today, these alloys are the most widely used shape memory and super elastic alloys, combining the most pronounced shape memory effect and super elasticity, corrosion resistance and biocompatibility, and superior engineering properties. Copper based alloys like Cu-Zn-Al and Cu-Al-Ni are commercially available too. These alloys are less stable and more brittle than Ni·Ti and therefore. Although less expensive have found only limited acceptance. In recent years, iron based shape memory alloys have been widely advertised. However, with their limited shape memory strain lack of ductility and other essential properties, these alloys will have to prove themselves as viable engineering materials.

The transformation temperatures of shape memory alloys can be adjusted through changes in composition. Ni-Ti as well as Cu-Zn-AI alloys show transformation temperatures between -100°C and +IOO' C, Cu-Al-Ni alloys up to 200' C. Unfortunately, Cu-AI-Ni alloys are not stable in cyclic applications. Some ternary Ni-Ti-Pd [3], Ni-Ti-Hf and Ni-Ti-Zr [4] alloys also are reported to exhibit transformation temperatures over 200°C. Although not commercially available today these alloys could eventually expand the applicability of the shape memory effect to much higher temperatures. In the following, only Ni-Ti alloys will be reviewed.

The hysteresis is an important characteristic of the heating and cooling behavior of shape memory alloys and products made from these alloys. Depending on the alloy used and for its processing, the transformation temperature as well as the shape of the hysteresis loop can be altered in a wide range. Binary Ni-Ti alloys typically have transformation temperatures (AO between O°C and lOO°C with a width of the hysteresis loop of 25'C to 4O' C. Copper containing Ni-Ti alloys show a narrow hysteresis of 7°C to 15 °C with transformation temperatures (Af) ranging from 10°C to approx. 80°C. An extremely narrow hysteresis of 0 to 5°C can be found in some binary and ternary Ni-Ti aJ10ys exhibiting a pre-martensitic transformation (commonly called R-phase). On the other hand, a very wide hysteresis of over 150°C can be realized in Niobium containing Ni-Ti alloys after a particular thermo mechanical treatment. Although low transformation temperatures (Af «O·C) can be reached with binary Ni-Ti alloys, those alloys tend to be brittle and difficult to process. For cryogenic uses, therefore, Fe-containing Ni-Ti alloys are commonly used.



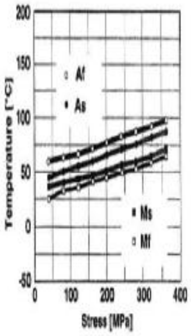


Fig. 4.4 (left): Influence of processing on the shape of the hysteresis loop (schematic)
Fig. 4.5 (right): Influence of applied stress on the transformation temperatures

The standard thermo mechanical processing of Ni-Ti alloys generates a steep hysteresis loop (a greater shape change with a lesser change in temperature), which generally is desirable in applications where a certain function has to be performed upon reaching or exceeding a certain temperature. Special processing can yield a hysteresis loop with a more gradual slope. i.e. a small shape Change with temperature. This behavior is preferred in applications where proportional control is required.

The shape of the hysteresis loop is not only alloy and processing dependent, but is also influenced by the application itself. IT a wire (standard processing) works against a constant load, e.g. by lifting a certain weight, the transition from manensite to austenite or vice versa occurs in a very narrow temperature range (typically SoC). However, if the wire works against a biasing spring, the transition is more gradual and depends on the rate of the spring.

5. FINITE ELEMENT ANALYSIS

It is a numerical procedure for analyzing structures and continua. Usually the problem addressed is too complicated to be solved satisfactorily by classical analytical methods. The Finite Element procedure produces many simultaneous algebraic equations, which are generated and solved on a digital computer. The Finite Element Method originated as a method of stress analysis. Today Finite Element Methods are also used to analyze problems of heat transfer, fluid flow, lubrication, electric and magnetic fields. Finite element procedures are used in design of buildings, electric motors, heat engines, ships, air frames and spacecrafts.

The Finite Element Method, in general, models a structure as an assemblage of small elements. Each element is of simple geometry and therefore is much easier to analyze than the actual structure. In many situations an adequate model is obtained using a finite number of well-defined components. Such problems are termed as Discrete. In others the subdivision is continued indefinitely and the problem can only be defined using the mathematical fiction of an infinitesimal. This leads to differential equations or equivalent statements that imply an infinite number of elements. Such systems are termed as Continuous.

FEA has become a solution to the task of predicting failure due to unknown stresses by showing problem areas in a material and allowing designers to see all of the theoretical stresses within. This method of product design and testing is far superior to the manufacturing costs, which would accrue if each sample was actually built and tested.

Many FEA programs also are equipped with the capability to use multiple materials within the structure such as:

- Isotropic, identical throughout
- Orthotropic, identical at 90 degrees
- General anisotropic, different throughout

5.1. CONVERGENCE

In practice, mesh grading is frequently necessary and the isoparametric elements show particular flexibility in achieving compatible graded meshes.

Compatibility is satisfied if the elements have the same nodes on the common face and the coordinates and displacements on the common face are in each element defined by the same interpolation functions.

The particular problem is repeatedly analyzed, each time using a finer mesh of elements, to generate a sequence of approximate solutions. Then the required mesh is chosen whose sequence of solution converges with that of theoretical exact solution.

5.2 BASIC CONCEPT OF FEM:

1. A complex region defining a continuum is discredited into simpler or smaller geometric shapes called finite elements.
2. The original body or the structure is then considered as an assemblage of these elements connected at a finite number of joints called nodes and nodal points.
3. Simple functions known as shape functions are chosen to approximate of variations actual displacements within each element in terms of the displacement at the nodes of the element.
4. The stresses and strains within an element are also expressed in terms of the nodal displacements.
5. Then the principle of virtual displacement or minimum potential energy is used to derive the equations of equilibrium for the element and the nodal displacements will be the unknown in the equation.
6. The equation of equilibrium for the entire structure or body are then obtained by combining the equilibrium equation of each element such that the continuity of displacement is ensure at each node where the elements are connected.
7. The necessary boundary conditions are imposed and the equations of equilibrium are solved for nodal displacements, which are the primary unknowns.

So it can be said that instead of solved the problem for the entire structure or body in one operation, finite element method of analysis lays emphasis mainly on the formulation of the properties of the constituent elements. The procedure for combining the elements, solution of equation and evaluation of element strains and stresses are the same for any type of structure or body. Hence FEM offers scope for developing general-purpose programs with the properties of various types of elements forming element library and the other procedures of analysis forming the common core systems. This modular structure of the program organization is well exploited in large number of commercial FEA programs.

5.3 .ISOPARAMETRIC GENERAL SHELL ELEMENTS:

Isoparametric means same parameters because either displacements or coordinates can be interpolated from nodal values.

1. Nodal d.o.f. {d} define displacements [u,v,w] of a point in the element $[u\ v\ w]^T = [N]\{d\}$
2. Nodal coordinates {c} define coordinates [x,y,zI of a point in the element $[x\ y\ z]^T\ [N]\{e\}$

An element is iso-parametric if [N] and [N] are identical i.e., the shape functions defining geometry and function are the same, the elements will be called isoparametric.

A shell of general shape can be modelled by 3-dimesional solid elements that have a thickness dimension considerably smaller than their other dimensions as shown in the figure. But even for a very thick shell three nodes along thickness- direction lines supply more d.o.f. than needed. Elimination of middle nodes yields the element of figure in which thickness -direction strain e is modelled as constant through the thickness. Here the subscript 3 indicates the direction normal to the shell mid-surface. As the element becomes even thinner stiffness coefficients associated with £3 become far larger than other stiffness coefficient. This circumstance invites numerical difficulties. The difficulty can be avoided by constraining adjacent thickness-direction nodes to have same thickness-direction displacement. Thus five d.o.f are associated with each pair of thickness direction nodes as shown in figure. These five d.o.f. is attached to a single node whose d.o,f is three translations and two rotations. These five d.o.f define the motion of a thickness direction line that remains straight but not necessarily normal to the shell mid surface after deformation. Thus the final element has mid surface nodes only.

An eight-noded degenerated isoparametric shell element is considered in the present case. The geometry of the element is defined by the global coordinates X, Y and Z. That is

$$X = \sum_{i=1}^{8} N_i X_i\ ,\ Y = \sum_{i=1}^{8} N_i Y_i \text{ and } Z = \sum_{i=1}^{8} N_i Z_i\ ,$$

Where the shape functions of the element N are given by

$$N_i = (1+\xi\xi_i)(1+\eta\eta_i)(\xi\xi_i+\eta\eta_i-1)/4 \qquad (i=1,4)$$

$$N_i = (1+\xi^2)(1+\eta\eta_i)/2 \qquad (i=5,7)$$

$$N_i = (1-\eta^2)(1+\xi\xi_i)/2 \qquad (i=6,8)$$

Where

η --- Local natural coordinate of an element

η_I --- Local natural coordinate of a node in an element (±1)

ξ ---- Local natural coordinate of an element

ξ_I ---- Local natural coordinate of a node in an element (± 1).

5.4 GENERAL ELEMENT FEATURES:

Many features are common to all ANSYS elements in the elements library. The individual elements constitute of

- Element name
- Nodes
- Degrees of freedom
- Real constants
- Material properties
- Surface loads
- Body forces
- Special features
- Key points.

5.5 ANALYTICAL SUPPORT:

Major Diameter	D = 0.l34m
Major Radius	R = 0.067m
Minor Diameter	d = 0.05m
Minor Radius	r = 0.025m

- Thickness of Shell T = 0.004m

5.6 ORTHOTROPIC PROPERTIES OF CARBON EPOXY:

- Ex =1 34 GPa
- Ey =7 GPa
- Ez =7 GPa
- GXY = 5.8GPa
- GXZ = 5.8GPa
- GYZ = 5.8GPa
- Density. ρ = 1.6.10 kg/m3,
- Poison’s Ratio, μ=0.3
- ISOTROPIC PROPERTIES OF SMA MARTENSITE:
- E = 26.3Gpa
- Density, ρ = 6448J Kg/rn3
- Poison’s Ratio, μ = 0.3
- Mean Radius R =D-T/2
- T/D=0.004/0.134=0.0303

If $\frac{T}{D}$ is less than $\frac{1}{15}$ it is a thin pressure vesse

If $\frac{T}{D}$ is greater than $\frac{1}{15}$ it is a thick pressure v

$$\frac{T}{D} = \frac{0.004}{0.134} = 0.03$$

This is the orginal $\frac{T}{D}$ ratio

- Total thickness of shell,
- T = 0.134 X 0.03 = 0.004 m
- For each layer, the thickness value is,

$$\frac{T}{8} = \frac{0.004}{8} = 0.0005m$$

Similarly for different $\frac{T}{D}$ ratios, each layer thickness

- AT 0.01 = 0.0001675m
- AT 0.02 = 0.000335m
- AT 0.03 = 0.00050m
- AT 0.04 = 0.00067m
- AT 0.05 = 0.0008375m
- AT 0.06 = 0.001005m
- AT 0.07 = 0.001 1725m
- AT 0.08 = 0.00134m

5.7. PRESSURE CONDITIONS:

The maximum allowable tensile strength of carbon epoxy is 880E6 N / m2.

The maximum allowable compressive strength of carbon epoxy is 60E6 N / m

So, the different pressure conditions within the allowable limit are

P1=921159 N/m²

P2=147.15 E4 N/m²

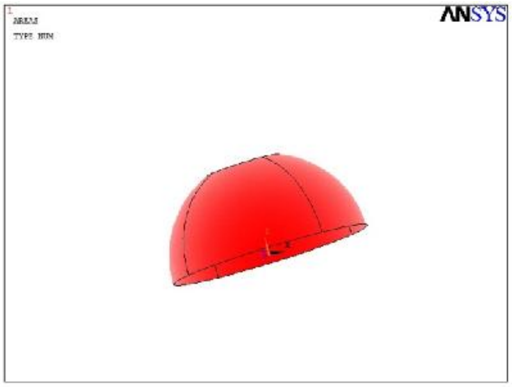


Fig. 5.1CAD model of spherical dom -1

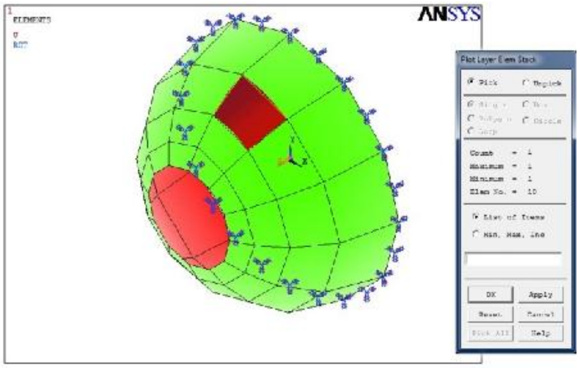


Fig. 5.2 To see shell layers for meshed model

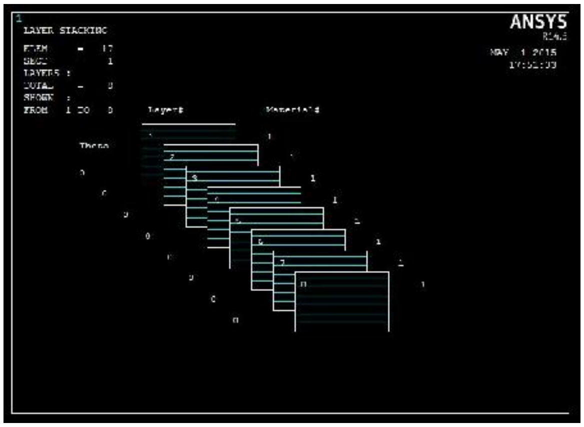


Fig. 5.3 Along the thickness layers formation shown on element no.17, withtheta –o degrees, material properties- set-1 and no. Layers – 8 nos.

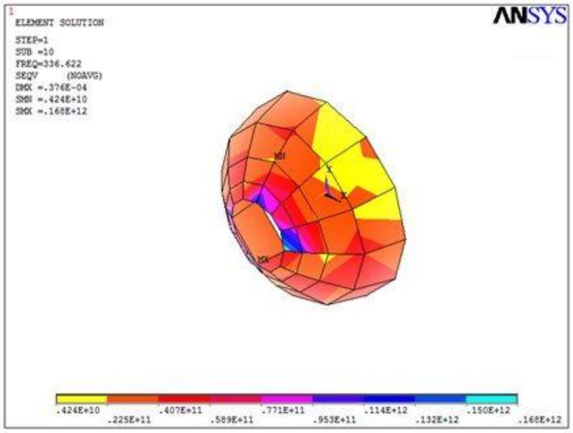


Fig. 5.4Von misses Stress in dom minimum stress – 424.0 E7 N/M2 (42.4e2 MPA) and Maximum – 166.0 E3 N/M2(166.0 E3 MPA) 90 degree orientation

6. RESULTS AND DISCUSSIONS

6.1 STATIC RESULTS:

6.1.1 LAYER LOCATION:

The SMA when fixed in location the value of maximum stress was found to be 0.21040E+08 in case of bolted condition and 0.1 1094E+08 in case of fixed condition. Similarly different values where observed with different fixation of SMA layers but the maximum stress was found in 7th layer with the maximum value of 0.2671 IE+08 in case of bolted condition and 0.19709E+08 in case of fixed condition. So, maximum stress was observed in case of 7th layer in both the boundary conditions.

6.1.2 DEGREE OF ORIENTATION:

The SMA layer being fixed and different orientations of CE were observed from 0 to 90 degrees then it was observed that at angle of 90 degrees we obtain a value of 0.21241E+08 which is the minimum value in case of bolted condition and 0.10635E+08 in case of fixed condition. So, minimum stress was observed at 90 degrees in both the boundary conditions.

6.1.3 T/D RATIO:

As T/D ratio increases the stress values were found to be decreased. When TID ratio is 0.01 the stress value was observed to be 0.99499E+08 in case of bolted condition and 0.4972E+08 in case of fixed condition, but as T/D ratio increased to a value of 0.08 it was found that stresses decreased and reach a value of 0.8759E+07 in case of bolted condition and 0.86672E+08 in case of fixed condition.

6.2 MODAL RESULTS:

6.2.1 LAYER LOCATION:

The SMA when placed in layer theist mode of frequency was observed to be 106.42 and 10th mode of frequency was 296.02, but the layer location changes the modes of frequencies increased to a value of 117.68 in case of 1st mode 323.08 in case of 10th mode in bolted condition. Similarly in fixed the value of 1 and 10th modes increased from 203.68, 576.56 to 208.08 and 555.12.

6.2.2 DEGREE OF ORIENTATION:

The SMA being fixed in the 7th layer and different orientations of CE from 0 to 90 degrees it was found that maximum values were found at 90 degrees with a value of 363.04 in case of bolted and 599.31 in case of fixed boundary conditions.

6.2.3 T/D RATIO:

An increase in T/D ratio increases the frequency values for different modes. When T/D ratio is at 0.01 the value of 1st mode was 32.546 and 10th mode was 122.94 in case of bolted condition and 76.325, 230.88 for the 1st and 10th modes in case of fixed condition. As the T/D ratios increased to 0.08 the values of and 10th modes in case of bolted condition increased to 280.88, 701.96 and in case of fixed condition the values of 1st and 10th modes increased to 566.15 and 1133.

6.3 STATIC RESULTS OF STRESSES (VONMISES) IN BOLTED CONDITION:

6.3.1 LAYER LOCATION:

LAYERS	MINIMUM VALUE (N/M^2)	MAXIMUM VALUE (N/M^2)
8CARBO	7.80E+06	2.10E+07
1ST SMA	6.72E+06	2.32E+07
2nd SMA	6.89E+06	2.26E+07
3rd SMA	6.99E+06	2.26E+07
4th SMA	7.04E+06	2.30E+07
5th SMA	7.07E+06	2.39E+07
6th SMA	7.07E+06	2.51E+07
7th SMA	7.03E+06	2.67E+07
8th SMA	5.83E+06	2.61E+07

The stress values of different layers which are under the load of the given condition the table represent the minimum and maximum values of the stresses.

6.3.2 DEGREES OF ORIENTATION:

DEGREES	MINIMUM VALUE (N/M^2)	MAXIMUM VALUE (N/M^2)
10	5.44E+06	2.62E+07
20	4.81E+06	2.31E+07
30	4.79E+06	2.74E+07
40	4.14E+11	3.24E+07
50	5.38E+06	3.28E+07
60	7.30E+06	2.93E+07
70	7.69E+06	2.44E+07
80	5.80E+06	2.18E+07
90	7.67E+06	2.12E+12

The stress values of different layers which are under the load of the given condition at different angles the table represent the minimum and maximum values of the stresses.

6.3.3 INCREASE IN T/D RATIO:

T/D RATIO	MINIMUM VALUE (N/M^2)	MAXIMUM VALUE (N/M^2)
0.01	1.69E+07	9.95E+07
0.02	9.87E+06	4.28E+07
0.03	7.00E+06	2.66E+07
0.04	5.53E+06	1.88E+07
0.05	4.66E+06	1.43E+07
0.06	4.08E+06	1.14E+07
0.07	3.66E+06	9.85E+06
0.08	3.34E+06	8.76E+06

The stress values of different layers which are under the load of the given condition at different thickness the table represent the minimum and maximum

6.4 STATIC RESULTS OF STRESSES (VONMISES) IN FIXED CONDITION:

6.4.1 LAYER LOCATION:

LAYERS	MINIMUM VALUE (N/M^2)	MAXIMIUM VALUE (N/M^2)
8	6.80E+06	1.43E+07
1ST	6.29E+06	1.11E+07
2nd SMA	6.36E+06	1.19E+07
3rd SMA	6.41E+06	1.29E+07
4th SMA	6.45E+06	1.42E+07
5th SMA	6.45E+06	1.57E+07
6th SMA	6.43E+06	1.75E+07
7th SMA	6.38E+06	1.97E+07
8th SMA	6.18E+06	1.59E+07

The stress values of different layers which are under the load of the given condition the table represent the minimum and maximum values of the stresses

6.5 GRAPHICAL REPRESENTATION OF MODAL RESULTS IN BOLTED CONDITION:

(AT P=147.15E4 NIM2)

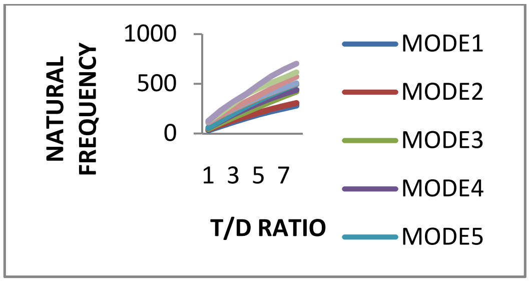


Fig. 6.1T/D RATIO VS NATURAL FREQUENCY

CONCLUSIONS

FEA consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design, and existing product refinement. A company is able to verify a proposed design will be able to perform to the clients specifications prior to manufacturing or construction. Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition.

From static results layer location, SMA condition maximum stress found in bolted condition rather than fixed conditions. By changing layer location, from results it found out is 7th layer has maximum stress. By degree of orientation SMA layer maximum stress occurred at 90 degree orientation, in both conditions (i.e., fixed and hinged). As per T/D ratio increases stress value found to be decrease. At T/D ration of 0.08 it is found to be decreases reaches to least value.

From modal analysis, layer location, degree orientation & T/D ration. Frequencies changed as per location, orientation &T/D ratio. This gives us idea about how frequency effects the change of attributes. Design effects with change properties of material & geometric.

A result it has been concluded has design effects on properties of material and geometric conditions. This gives us to study how behaviour of material of SMA by changing properties. So, gives us an idea to approach a problem in SMA and how it behaves with changes.

In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition. FEA uses a complex system of points called nodes, which make a grid called a mesh. This mesh is programmed to contain the material and structural properties, which define how the structure will react to certain loading conditions. Nodes are assigned at a certain density throughout the material depending on the anticipated stress levels of a particular area. Regions, which will receive large amounts of stress usually, have a higher node density than those, which experience little or no stress. Points of interest may consist of fracture point of previously tested material, fillets, corners, complex detail, and high stress areas. The mesh acts like a spider web in that from each node, there extends a mesh element to each of the adjacent nodes. This web of vectors is what carries the material properties to the object, creating many elements.

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