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Composites at Cryogenic Temperature

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Abstract : Fiber reinforced composites are class of materials that are workable engineering materials possessing high strength to weight ratio resulting in reduction of weight and hence savings in energy. Composites can be tailor -made to the required duty by changing the nature and proportion of the constituent materials. Composites exhibit anisotropy in mechanical and thermal properties. This makes the design of composite structures more complex and demanding. Composites have wide applications as supports and structures at cryogenic temperatures in super conducting magnets and as fuel tankage in spacecraft and rocketry. As these composites are fabricated at 1000 C to 2000 C, ~ their use at low temperatures creates thermal stresses. They become brittle at low temperatures and thermal strain of matrix ma:f be of the same order of the ultimate tensile strain at helium temperature (4.2K); thus leaving no more load bearing capability.

Keywords – *Nano, Polarization, Zinc-Nickel, Layers*

I. INTRODUCTION

1.1 Composite Materials

Heat conduction problem is solved using ANSYS 5.4 (a standard software package). Two-dimensional thermal stress problem adopting higher order deformation theory is formulated. Numerical analysis of the problem is carried out using Finite Element Method with 8 node iso- parametric Elements. A program in a modular form is developed and tested for thermal stresses. The temperatures and thermal stresses obtained are plotted in Cartesian directions. The inferences drawn from the results and graphs are presented as conclusions along with scope for future work. Finally it is concluded that for cryogenic duty, angle ply laminated composite support, with fiber orientation Angles well below 90^0 are better choice to limit thermally induced stresses.

Composite materials or composites are combination of two or more materials that have properties significantly different from its constituent materials. The technology of composite materials has made them workable engineering materials. The composite materials exhibit high modulus per unit weight (or specific modulus) and also high strength per unit weight (or specific strength), resulting in substantial reduction of weight of the components; thus enhancing the efficiency and results in energy savings. The properties of composite materials Can be varied over a wide range by changing the proportions and nature of Constituent materials. The anisotropy of composite materials (i.e.) large difference in mechanical and transport properties in different directions impose certain limitations in some applications. The outstanding advantage of composite materials is the flexibility involved in obtaining the desired strength and stiffness in the product in the direction it is required. This introduces a great flexibility in design and makes the design of the product more complex and demanding. The Laminated composites can be designed to possess many desired properties like Corrosion resistance, surface hardness, wear resistance, impact resistance and Enhanced heat transfercharacteristics.

The main purpose of matrix is to transmit the load to the fiber which is the main load bearing constituent of the interface. Based on the properties that are desired the matrix arid fiber materials are selected.

II. THERMAL STRESSES IN COMPOSITE MATERIALS

Composites are generally fabricated at typical temperatures viz.' 100^0 to 200^0 C, followed by cooling to room temperature which is generally the operating temperature. As individual plies in the laminate are constrained, they are not free to undergo thermal deformations. The thermal deformation of each layer is influenced by other layers. As a result thermal stresses are set up in the material. Thermal stresses are also induced in the material due to difference in thermal and transport properties of the constituent material of the composite. These residual thermal stresses may cause premature failure, warping etc. So, in defining a composite due consideration shall be given to thermal stresses.

Thermal strains do not produce either a resultant force or moment when the body is completely free to deform. The stresses are induced by constraints placed on its deformation by adjacent laminae. The stresses in the laminae are produced, only by the constraints placed on its deformation by its adjacent laminae. The stresses in the laminae are produced by strains, in excess of thermal strains, due to its expansion. These excess strains that cause stresses are referred to as mechanical strains. In some cases such residual stresses or curing stresses may be sufficiently large to influence the failure of laminae and thus should not be neglected in design analysis.

III. METHODOLOGY

So to evaluate realistic thermal stresses in a given thick composite laminated plate, temperature values at designated node are used.In view of certain lacunae in the literature available for thermal stress analysis a displacement finite element formulation based on higher order theory has been developed .This methodology permits prediction of realistic flexural behavior Incorporating the temperature distribution obtained. The temperature variation across each layer of laminated composite plate is found to be non-linear. An eight-node iso parametric quadratic quadrilateral element is selected for discrediting the composite laminated plate, shown in the physical model, in two-dimensional heat conduction problem and also in two-dimensional model, in two-dimensional heat conduction problem and also in two-dimensional finite-element model for thermo-elastic analysis. ANSYS 5.4 is used for solving two-dimensional heat conduction problem.

IV. RESULTS AND DISCUSSIONS

4.1Thermal Stresses And Deformations

The discussions on the results obtained from computer program for two-dimensional finite element formulation for thermal stresses and deformations are given in this chapter. The input to thermal stress analysis includes the realistic temperature distribution obtained from the two-dimensional heat conduction finite element analysis of chapter 5 for the thermal boundary conditions specified therein.

Appropriate S. I. Units are used for geometric dimensions (m), physical properties, stresses (Pa), deformations (m). The terms (SIGX) and (SIGY), are used in the graphs indicate crx and cry respectively. Three different types namely homogeneous (unidirectional), angle ply and hybrid composite plates are considered for thermal stress analysis. 6.1 Unidirectional Composite Plates: In this category six different materials with combination of matrix material Peek and three fiber materials viz. Carbon, Glass and Kevlar with a fiber volume fraction of 0.6

V. CONCLUSION

The two-dimensional thermal field obtained in angle-ply laminate (0°, 45°,90°, -45°, 0°) FRP reveals that the temperature variation along the breadth-(or thickness) direction of the support is non-linear. The above thermal analysis on composite support also indicates that the temperature distribution in length direction is linear and straight. It is clear that thermally induced stresses are significantly influenced by the fiber material and orientation angle of these fibers in the laminate. It is finally observed that for the duty of cryogenic supports angle-ply composite laminate with a maximum fiber orientation angle well below 90^0 are better choice in view of limiting thermally induced stresses.

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