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DISCUSSIOMG CONCEPT RELATED TO FREE VIBRATION ANALYSIS

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ABSTRACT

Composite materials are replacing metals in many structural applications such as aerospace, transportation, novel and pressure vessels due to their high specific strength and specific modulus. The dynamic responses of these structures differ from that made of isotropic materials due to the orthotropic nature of individual layers of the laminate. Free vibration analysis is a part of dynamic analysis where the natural frequencies of the structure can be estimated. The composite structures may sometimes be provided with different types of holes for the purpose of assembling the components and units inside the structure, for passing the cables and control mechanisms, for inspection, maintenance and attachment to other units. The influence of the thickness parameter is inherent at higher modes of vibration. In addition, providing skew angle for plates alters the stiffness of the plate. The classical lamination theory is limited to very thin plates and other classical solution tools do not give closed form solutions due to the discontinuity in geometry, boundary conditions and materials. In such situations a finite element method which uses the three dimensional elasticity theory for the evaluation of stiffness matrices will give an approximate solution to the desired accuracy.

Keywords: - Materials, Elasticity, Vibration, Geometry, Element Method.

I. INTRODUCTION

ENGINEERING MATERIALS

From the known history, many materials have come to an extent they are used to design and production. Some materials are of ordinary type like copper, cast iron, etc., and some are of advanced type like composites, ceramics, etc. Further the materials are classified depending on their characteristics into Metals, Plastics, Ceramics and Composites [103]. However, each type contains a large number of materials with a sort of properties.

Metals

Generally the metals are the superior ones because of their strength and stiffness. The mixture of metals called alloys. These alloys are formed by mixing two or more metals. Metals are more heavy and high temperature resistance when compared with plastics, composites and ceramics. They can be used for applications with higher service temperature requirements, due to their higher temperature resistance than plastics.

Plastics

Recently from past decade, plastics are becoming more common engineering materials than steel or metals. Plastics are being widely used in applications like automobile, aerospace, etc., depending on their wide properties with the assist of manufacturing methods; plastics can be created into net-shape parts otherwise nearnet-shape. These plastics are available in the form of sheets, rods, bars, powders and granules. However, plastics cannot be worn-out for high temperature applications.

Ceramics

Ceramics are formed by strong covalent bonds, they have greater thermal stability and high hardness. The major distinctive characteristic of ceramics as compared to metals is that they acquire almost no ductility. Ceramics include properties like high temperature and high wear applications, high melting points; these are failing in brittle fashions. Special types of metallurgical techniques are required for manufacturing of ceramics. Ceramics are difficult to machine they require expensive, cutting tools.

Composites

Composites are commonly used materials in applications with better performance like automotive components, aerospace parts, marine and oil industries. Fiber-reinforced composite materials vary from the beyond materials in that the constituent materials are dissimilar at the molecular level and are mechanically separable. Having the property of light weight and the demand for light weight products in manufacturing has increased the use of composites widely. Composites parts can replace steel parts and reduce 60 to 80% of total weight and 20 to 50% in the case of aluminum parts.

II. FREE VIBRATION ANALYSIS

If anybody at rest is disturbed in the appropriate manner initially at time t=0 the body will oscillate, this oscillatory motion of the body is the characteristic property of the body. This concept of the body depends on mass and stiffness in the body. However, when damping is absent, the damping motion will continue indefinitely with the amplitudes of oscillation depending on the initially imposed disturbance or deformation or displacement. The oscillatory motion takes place at certain frequencies known as natural frequencies or characteristic values, and it obeys well defined transformation patterns known as mode shapes or characteristic modes Oscillatory motion manifest itself at frequencies like natural frequencies or at characteristic values and it follows well defined transformation arrangements known as mode shapes or characteristic modes.

FINITE ELEMENT METHOD

The finite element method is a numerical course of action for analyzing structures and continuum. The finite element procedure generates many simultaneous algebraic equations, which are procreated and unraveled on a digital computer. However, errors are decreased by processing more equations, and the results accurate enough for engineering purposes are obtained at rational cost.

The finite element method is acclimated to anatomize problems of vibration analysis, heat transfer, fluid flow, lubrication, electric and magnetic fields and many others. Problems that previously were utterly intractable are now solved routinely. Finite element procedures are used in the design of buildings, electric motors, heat engines, ships, airframes, and spacecrafts. Manufacturing companies and large design offices typically have one or more large finite element programs in-house. Smaller companies usually have access to a large program through a commercially computing center or use a small program on a personal computer.

The finite element method is a method of elemental approximation in which the approximating function φ is formed by connecting simple functions, each defined over a small elemental region. A finite element is a region in space in which a function φ is interpolated from nodal values of φ on the boundary of the region in such a way that interelement continuity of φ tends to be maintained in the assemblage.

The power of the finite element method has depended mainly on its multifaceted attribute. Various physical problems can be compiled by this method. The analyzed body can have arbitrary shape, loads, and support conditions. This method can mix elements of different types, shapes, and physical properties. This great versatility is enveloped within a single computer program. User-prepared input data manages the selection of problem type, geometry, boundary conditions, element selection, and so on.

III. FRP COMPOSITES: CONSTITUENTS AND CHARACTERISTICS

The structural materials consisting more than one or two combined materials at a macroscopic level is called composite that are not soluble. The composite materials can be divided in two phases namely matrix and reinforcement. There are three phases of reinforcing materials i.e. particles, fibers, and flakes. The physical and chemical identities of fibers and matrix are kept intact in FRP composite materials. Thus, FRP composites exhibit better qualities as compared to the conventional method of fabrication and fabricating agent and hence, find tremendous applications in the aircraft, aerospace and automobile structures [10]. The principal load carrying members are fibers, whereas the function of matrix is to transfer the load and keep them at pre-determined position and orientation. The basic constituents of composite material systems are the reinforcements, the matrix (usually epoxy or polyester) and the coupling agents (coatings/fillers).

According to the reinforcement type, they are classified as:

i) Fibrous: Composed of continuous or chopped fibers
ii) Particulate: Composed of particles
iii) Laminated: Composed of layers or laminae with desired fibre orientation
iv) Flake: Composed of flat flakes reinforcements

The FRP composites are used in large scale in the composite piping systems due to the improved properties such as specific strength, specific weight, corrosion resistance, wear resistance, fatigue life, stiffness, thermal conductivity, acoustical insulation, thermal insulation, etc. Unlike traditional monolithic materials, FRP composites can have their strengths oriented to acquire the specific design needs. The classifications of the FRP composites have been shown in Figure 1.1. Real composite structures consist of multi layered laminae having different ply orientations of continuous fiber. A wide variety of fibers and matrix materials are available for use in the composite piping systems. The principal fibers preferably used in the composite piping systems are various types of Glass, Carbon, Graphite, Aramid as well as Kevlar. Other fibers, such as Boron, Silicon Carbide and Aluminum Oxide are used in limited applications. All these fibers are incorporated into the appropriate matrix phase in continuous or discontinuous (chopped) lengths. The matrix material may be a polymer, a metal or a ceramic. Specific fillers, additives and core materials are also sometimes added to enhance and modify the final product.

IV. JOINING OF LAMINATED FRP COMPOSITES

Adhesive bonding represents one of the most important qualifying technologies that has revolutionized construction and manufacturing in different fields of structural engineering. The ever increasing demand of adhesive in structural engineering has not only caused an evolution of the adhesive bonding method but also has attracted many researchers to dig deeper into the possibility. Although structural bonded joints may not appear to be complex even to a lay man, however there lies a great deal of technical intricacies that may reveal the longevity, stiffness, strength and ensure structural success even in harsh environments. Compared to other mechanically fastened joints, adhesive bonded joints can offer substantially improved performance and economic advantages. Adhesive bonding connection method is mostly used in joining the composite materials for its effectiveness in terms of minimum stress concentration and smooth load transfer between the connecting members. Adhesives also provide corrosion free life of the joints. Analysis and design of adhesively-bonded tubular joint is a multi-disciplinary task and it involves concepts from the surface and polymer chemistry, stress analysis, manufacturing technology and fracture mechanics. The following important aspects need to be considered for designing the adhesive bonded joints when used in structural applications.

- Selection of suitable adhesive and its characteristics
- Appropriate surface preparation of adherends
- Development of joint design based on failure analysis

This thesis is intended to focus on various aspects of analysis and design of laminated FRP composite made bonded tubular joints, including stress analysis, strength prediction and failure analysis.

V. CONCLUSION

The free vibration analysis of thick skew laminated FRP composite plate with a circular cutout has been studied in the present work. The effect of material parameters such as i) cross-ply laminates, ii) angle-ply laminates and iii) laminates with

general stacking sequences of single and hybrid materials, and the geometric parameters such as i) skew angle (α), ii) cutout dia. to length ratio (d/l) and iii) length to thickness ratio
(s) of structure with all edges clamped are studied. Effect of support conditions is also studied for a case where other parameters are kept constant. Prior to this, the 3-D finite element method is validated with existing theoretical methods and with the experiments that are specially designed for this purpose.

The following conclusions are drawn:

- The present 3-D FEM is validated with the results of different theories and found very close agreement for the natural frequency values. FEM results are also found to be in good agreement with the majority of the experimental results that are carried out as part of the present work. A deviation of 5% for a double thickness specimen of AL+AL, and 6.72% in the case of composite specimens is observed. Finite element method can be used for the evaluation of natural frequency of composite structures.
- <u>Analysis of cross-ply laminates</u>:

For the consider range of d/l, α, s and n, the least frequency is observed for a thickness ratio of 80 at a skew angle of 0^o and the maximum frequency is observed for a thickness ratio of 5 at a d/l ratio of 0.6.

- <u>Analysis of Angle-ply laminates</u>:

For the consider range of θ, d/l, α, s and n, the minimum frequency is observed for a thickness ratio of 80 at a fiber angle of 10^o and the maximum frequency is observed for a fiber angle of 90^o at a skew angle of 50^o.

- <u>Laminates with general stacking sequences:</u>

For the consider value of d/l, α, s and n, the different stacking sequences of 0 and 90 lamination schemes, 10^o to 90^o fiber angles, the least frequency is observed in a stacking sequence of (+θ/+θ/+θ/+θ) at 30^o fiber angle and the maximum frequencies are observed for stacking sequences (+θ/+θ/-θ/-θ), (+θ/-θ/-θ/+θ) at a 90^o fiber angle and also in (90/90/90/90) lamination scheme.

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