MODAL ANALYSIS AND STUDY OF CRACK ON HYBRID LAMINATED COMPOSITE PLATE

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ABSTRACT

This study investigates the modal analysis of hybrid laminated sandwich composite plate. The laminated composite structures are being increasingly used in automotive, aerospace, marine and high-end applications. Composite materials have unique properties like high strength to weight ratio, non-corrosive, good surface finish etc. Properties of composite material can be tailored as per requirement. The finite element model of the laminated composite sandwich plate is developed by using ANSYS and ABAQUS software. The developed finite element models are validated with the available literature. Various parametric studies are carried out in terms of natural frequencies, mode shapes and crack propagation to describe the effectiveness of laminated composite sandwich plate. The results suggest that the fiber angle orientation, stacking sequence of laminates and the boundary conditions are influencing the natural frequencies and mode shapes of the laminated composite sandwich plate. Also, comparative studies are done in terms of natural frequencies, stresses obtained between GFRP,CFRP, Boron and Kevlar.

INTRODUCTION

HISTORY

The oldest example of composites dating back to 4000B. Cist he addition of straw to clay to make bricks stronger. In this combination, the straws are the reinforcing fibers and the clay is matrix.

Another example of a composite material is reinforced concrete which was developed in the 1800s. By itself, concrete is brittle and has little or no useful tensile strength; reinforcing steel rods (rebar) impart the necessary tensile strength.

Glass Fibers

Glass fiber is a generic name like carbon fiber or steel or aluminum. Just as different compositions of steel or aluminum alloys are available, there are many of different chemical compositions of glass fibers that are commercially available. Common glass fibers are silica based (~50–60 % SiO_2) and contain a host of other oxides of calcium, boron, sodium, aluminum, and iron, for example. There are three types of glass fibers. They are E glass, C glass, S glass. The designation E stands for electrical because E glass is a good electrical insulator in addition to having good strength and a reasonable Young's modulus; C stands for corrosion and C glass has a better resistance to chemical corrosion than other glasses; S stands for the high silica content that makes S glass, withstand higher temperatures than other glasses. It should be pointed out that most of the continuous glass fiber produced is of the E glass type but, notwithstanding the designation E, electrical uses of E glass fiber are only a small fraction of the to market.

Boron Fibers

Boron is an inherently brittle material. It is commercially made by chemical vapor deposition (CVD) of boron on a substrate, that is, boron fiber as produced is itself a composite fiber. In view of the fact that rather high temperatures are required for this deposition process, the choice of substrate material that goes to form the core of the finished boron fiber is limited. Generally, a fine tungsten wire is used for this purpose. A carbon substrate can also be used. The first boron fibers were obtained by Weintraub (1911) by means of reduction of a boron halide with hydrogen on a hot wire substrate. There impulse in boron fiber fabrication, however, came in1959, when Talley (Talley1959; Talley etal.1960) used the process of halide reduction to obtain amorphous boron fibers of high strength. Since then, interest in the use of strong but light boron fibers as a possible structural component in aerospace and other structures has been continuous, although it must be admitted that this interest has periodically waxed and waned in the face of rather stiff competition from other so called advanced fibers, in particular, carbon fibers.

Carbon Fibers

Carbon is a very light element with a density equal to 2.268g/cm3.Carbon can exist in a variety of crystalline forms. Our interest here is in the so-called graphitic structure wherein the carbon atoms are arranged in the form of hexagonal layers. The other well-known form of carbon is the covalent diamond structure wherein the carbon atoms are arranged in a three- dimensional configuration with little structural flexibility. Another form of carbon is Buckminster Fullerene (or Bucky ball), with a molecular composition of C_{60} or C_{70}. One can also have carbon nanotubes, which are nothing but drawn out version of Bucky balls. Carbon in the graphitic form is highly anisotropic, with a theoretical Young's modulus in the layer plane being equal to about1, 000 GPa.

The graphite structure has a very dense packing in the layer planes. The lattice structure is shown more clearly with only lattice planes in. As we know, the bond strength determines the modulus of a material. Thus, the high-strength bond between carbon atoms in the layer plane results in an extremely high modulus while the weak Vander Waals type bond between the neighboring layers results in a lower modulus in that direction. Consequently, almost all processing techniques of carbon fiber have the goal of obtaining a very high degree of preferred orientation of hexagonal planes along the fiber axis. Carbon fibers of extremely high modulus can be made by carbonization of organic precursor fibers followed by graphitization at high temperatures.

The organic precurs or fiber, that is, the raw material for carbon fiber, is generally a special textile polymeric fiber that can be carbonized without melting. The precursor fiber, like any polymeric fiber, consists of long-chain molecules (0.1–1 mm when fully stretched) arranged in a random manner. Such polymeric fibers generally have poor mechanical properties and typically show rather large deformations at low stresses mainly because the polymeric chains are not ordered. A commonly used precursor fiber is poly acrylonitrile (PAN). Other precursor fibers include rayon and the ones obtained from pitches, polyvinyl alcohol, polyimides, and phenolics. Carbon fiber is a generic term representing a family of fibers. As pointed out earlier, unlike the rigid 5 diamond structure, graphitic carbon has a lamellar structure. Thus, depending on the size of the lamellar packets, their stacking heights, and the resulting crystalline orientations, one can obtain a range of properties.

Kevlar Fibers

Kevlar is an organic fiber in the aromatic polyamide (aramid) family that combines high strength with light weight, and comfort with protection. Kevlar is five times stronger than steel on an equal weight basis and provides reliable performance and solid strength. This unique combination of attributes ensures that members of law enforcement, corrections personnel and the military will be safe from harm that can come in many forms, including bullets, knives, switchblades and shrapnel. In fact, Kevlar garments have so far saved the lives of nearly 3,000 law enforcement officials.

DuPont discovered Kevlar in 1965. Before then, scientists knew that chemical bonds between atoms were very strong, but researchers were unable to arrange these molecules into large structures (relative to the size of a molecule) to capitalize on this.

CRACK

A crack is a type of fracture that separates a solid body into two, or more, pieces under the action of stress. There are three types of modes of failure.

Model: The forces are perpendicular to the crack (the crack is horizontal, and the forces are vertical), pulling the crack open. This is referred to as the opening mode.

Mode II: The forces are parallel to the crack. One force is pushing the top half of the crack back and the other is pulling the bottom half of the crack forward, both along the same line. This creates a shear crack. The crack is sliding along itself. It is called in-plane shear because the forces are not causing the material to move out of its original plane.

Mode III: The forces are perpendicular to the crack (the crack is in front-back direction, the forces are pulling left and right). This causes the material to separate and slide along itself, moving out of its original plane (which is why it is called out-of-plane shear).

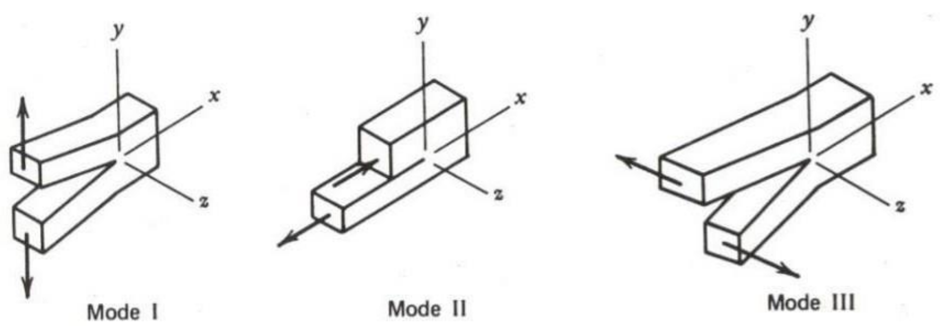

Fig. Modes of cracks

Cracks can form

- Due to fatigue
- Because of manufacturing processes (i.e. deep machining marks or void sin welds)
- And metallurgical discontinuities (i.e. inclusions).

DEFECTS

An important factor in fracture is the presence of defects, such as scratches, flaws and existing external or internal cracks. Under tension, the sharp tip of the crack is subjected to high tensile stresses, which then lead the crack to propagate rapidly.

Fracture and Damage mechanics

Cracks and flaws occur in many structures and components, sometimes leading to disastrous results. The engineering field of fracture mechanics was established to develop a basic understanding of such crack propagation problems.

Fracture mechanics deals with the study of how a crack or flaw in a structure propagates under applied loads. It involves correlating analytical predictions of crack propagation and failure with experimental results. The analytical predictions are made by calculating fracture parameters such as stress intensity factors in the crack region, which you can use to estimate crack growth rate. Typically, the crack length increases with each application of some cyclic load, such as cabin pressurization- depressurization in an aero plane. Further, environmental conditions such as temperature or extensive exposure to irradiation can affect the fracture propensity of a given material.

De bonding, Fiber Pullout, and De lamination Fracture

De bonding of the fiber/matrix interface, fiber pullout, and de lamination fracture are some of the features that are commonly observed in fiber reinforced composites; these modes of fracture are not observed in conventional, monolithic materials.

Consider the situation where in a crack originates in the matrix and approaches the fiber/matrix interface. In a short fiber composite with a critical length l_C, fibers with extremities within a distance $l_C/2$ from the plane of the crack will de-bond and pullout of the matrix. These fibers will not break. In fact, the fraction of fibers pulling out will be l_C/l. Continuous fibers ($l > l_C$) invariably have flaws distributed along their length. Thus, some of them may fracture in the plane of the crack, while others may fracture away from the crack plane. This is treated in some detail later in this section. The final fracture of the composite will generally involve some fiberpullout.

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