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A Study on Analysis of Circular Laminates under Transverse Loads using Ansys

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ABSTRACT

Laminated composite structures find numerous applications in civil engineering, aerospace, military and automotive industries. In the present work, four layered (□ 0/□ 0/□ 0/□ 0) clamped symmetric laminated circular plate with equal thickness of layers, under uniformly distributed load and central point load have been analyzed through the finite element technique using ANSYS. The material taken is E-epoxy [11] glass fibers included in a matrix of nestropol-450 unsaturated polyester resin and its properties used are as follows:E1 = 39000 N/mm2, E2 = E3 = 8600 N/mm2,G12 = G23 = G13 = 3800 N/mm2,□ □ 12 =□ □ 13 = 0.25 and□ □ 23 = 0.42.The uniform pressure (q) and central point load (P) are taken 0.2 N/mm2 and 10 N respectively for analysis in the present work. The variation of maximum stresses (σxx, σyy, τxy, τxz, τyz) and maximum radial. The observations due to the effect of modular ratio (E1/E2) 5, 10, 15 and 30 on central deflection (w), stresses (σxx, σyy, τxy, τxz, τyz) and radial stresses (σr, σΘ, rΘ) of square plate for radius-to-thickness ratio (r/h) 5, 10, 50 and 100 are: The deflection (w) decreases as modular ratio (E1/E2) increases and are maximum for E1/E2 =5. (ii) The stresses (σxx, σyy, τxy) and radial stresses (σr, σΘ, τrΘ) increases as modular ratio (E1/E2) increases and are maximum for E1/E2 = 30 for four layered circular clamped laminate under uniform pressure.

The deflection (w) increases as radius to thickness ratio (r/h) increases and is maximum for r/h = 100. (iv) The stresses (σxx, σyy, τxy, τyz, τxz) and radial.

INTRODUCTION

Lately, propelled composite materials are in effect progressively utilized as a part of numerous designing and non-military personnel applications, running from fuselage of a plane to the casing of a tennis racket. The high stiffness-to-weight ratio, coupled with the flexibility in the selection of lamination scheme that can be tailored to match the design requirements, make the laminated plates attractive structural components for automotive and aerospace vehicles. The increased use of the laminated plates in various structures has created considerable interest in their analysis. A fibrous composite material generally has the fibers of glass, steel, graphite, boron, carbon etc. that is generally bound together by embedding them using a matrix. Few matrix materials being used are polyester, epoxy phenolics etc. Fiber reinforced composite materials, for example contain high strength and high modulus fibers in a matrix material. In these composites, fibers are principal load bearing members and matrix material keeps the fibers together, acts as a load transfer medium between fibers and protects fibers from being exposed to the environment.

Recent years have witnessed an increasing use of advanced composite materials (e.g. graphite/epoxy, boron/epoxy, Kevlar/epoxy, graphite/PEEK etc.), which are replacing metallic alloys in the fabrication of load bearing plate type structures because of many beneficial properties, such as higher strength-to-weight ratios, longer fatigue (including sonic fatigue) life, better stealth characteristics, enhanced corrosion resistance and most significantly, the possibility of optimal design through the variation of stacking pattern, fiber orientation and so forth known as composite tailoring.

LITERATURE REVIEW

Pandya and Kant (1988) presented a finite element formulation for flexure of a symmetrically laminated plate based on a higher-order displacement model and a three-dimensional state of stress and strain. They incorporated linear variation of transverse normal strains and parabolic variation of transverse shear strains in higher order. They described a nine-nodded Lagrangian parabolic isoperimetric plate-bending element and described the applications of the element to bending of laminated plates with various loading, boundary conditions and lamination types.

Zinno and Barbero (1995) developed a three-dimensional element with two-dimensional kinematic constraints for the geometric nonlinear analysis of laminated composite plates using a total Lagrangian description and the principle of virtual displacements.

Voyiadjis and Woelke (2004) presented a theory for thick spherical shells. The equations given did not only incorporate the effects of transverse shear deformation but also account for the initial curvature as well as the radial stress. Their proposed theory presented a very good approximation for the shell constitutive equations and the nonlinear distribution of the in-plane stresses across the thickness of the shell.

Naghipour et al. (2008) performed the numerical simulations of laminated composite plates to decrease the weight of Military Mobile Bridges (MMB) using first order shear deformation theory and classical laminate plate theory. They studied the effects of fibre orientation, number of layers and stiffness ratio on the displacement and stress response of symmetric and anti-symmetric laminated composite plates subjected to uniform pressure loads.

Thai et al. (2012) presented a novel finite element formulation for static, free vibration and buckling analyses of laminated composite plates. The idea relied on a combination of node-based smoothing discrete shear gap method with the higher-order shear deformation plate theory (HSDT) to give a so-called NS-DSG3 element. They introduced the higher-order shear deformation plate theory (HSDT) in the method to remove the shear correction factors and improve the accuracy of transverse shear stresses. The formulation used only linear approximations and its implementation into finite element programs was quite simple and efficient.

Kale and Chapkhane (2013) carried out finite element analysis of orthotropic laminated composite plate using refined first order shear deformation theory. They found that stacking sequence had a significant effect on the normal stress through the thickness of laminate. They used classical lamination theory in the stress analysis of composite laminate. However it was observed that classical lamination theory was only accurate for thin composites laminates. As the thickness of laminate increased the shear effect becomes predominant and CLT and FEA results did not match each other.

METHODOLOGY

Composite materials consist of two or more materials, which together produce desirable properties that cannot be achieved with any of the constituents alone. Since laminated composites are made of different material layers, the material property is discontinuous through thickness. This material mismatch across the laminate interfaces makes the analysis of composite structures very complicated. The Classical Lamination Theory ignores the transverse shear deformation, which may have significant effects on the behavior of moderately thick laminated plates because their effective transverse moduli are much smaller than the effective elastic moduli along the fiber direction.

First-order shear deformation theory given by Kam, T.Y. and Chang, R.R.[15] for laminated anisotropic plates includes transverse shear effects by considering shear correction factors which has not been considered in classical lamination theory (CLT).

The displacement field is assumed to be of the following form:

$u = uo + z\Box\ x$ (3.2.1)
$v = vo + z\Box\ y$ (3.2.2)

In modern world design process has been too close to precision so the use of finite element method is extensive. It is being used as the most trustworthy tool for designing. It helps to predict the behavior of various products, parts, subassemblies and assemblies.

Analyzing the results helps to prevent the time of prototyping and reduces the expense due to physical test. It also increases the innovation at a faster and more accurate way. Analysts and designers work together to find the most appropriate answer using the most optimized tool.

ANSYS is now being used in a number of different engineering fields such as power generation, transportation, medical components, electronic devices, and household appliances.

SHELL93 is particularly well suited to model curved shells. The element has six degrees of freedom at each node: translations in the nodal x, y, and z directions and rotations about the nodal x, y, and z-axes. The deformation shapes are quadratic in both in-plane directions.

The element has plasticity, stress stiffening, large deflection, and large strain capabilities. The element is defined by eight nodes, four thicknesses, and the orthotropic material properties.

Midsize nodes may not be removed from this element. A triangular-shaped element may be formed by defining the same node number for nodes K, L and O.

RESULT

A four layered (□ 0/□ 0/□ 0/□ 0) clamped symmetric laminated circular plate with equal thickness of layers, under uniformly distributed load and central point load have been analyzed through the finite element technique using ANSYS.

The material taken is E-epoxy [11] glass fibers included in a matrix of nestropol- 450 unsaturated polyester resin and its properties used are as follows:

E1 = 39000 N/mm2, E2 = E3 = 8600 N/mm2,

G12 = G23 = G13 = 3800 N/mm2,□ □ 12 =□ □ 13 = 0.25 and□ □ 23 = 0.42

The uniform pressure (q) and central point load (P) are taken 0.2 N/mm2 and 10 N respectively for analysis in the present work.

CLAMPED FOUR LAYERED SYMMETRIC ($0^0/0^0/0^0/0^0$) CIRCULAR LAMINATE UNDER UNIFORM PRESSURE

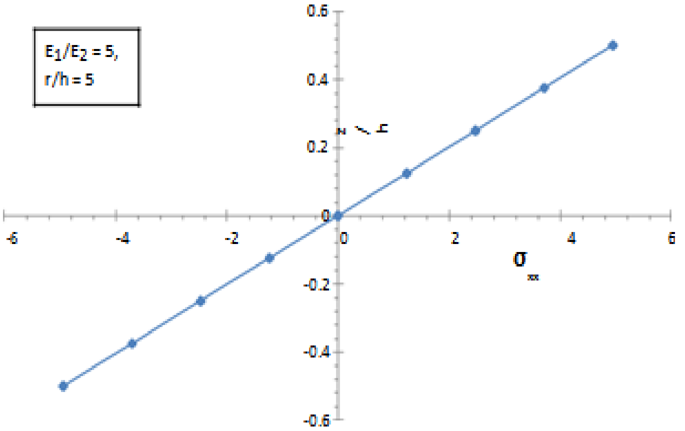

Fig. 4.1 Variation of stress in X-direction (σ_{xx}) through thickness (z/h) under uniform pressure

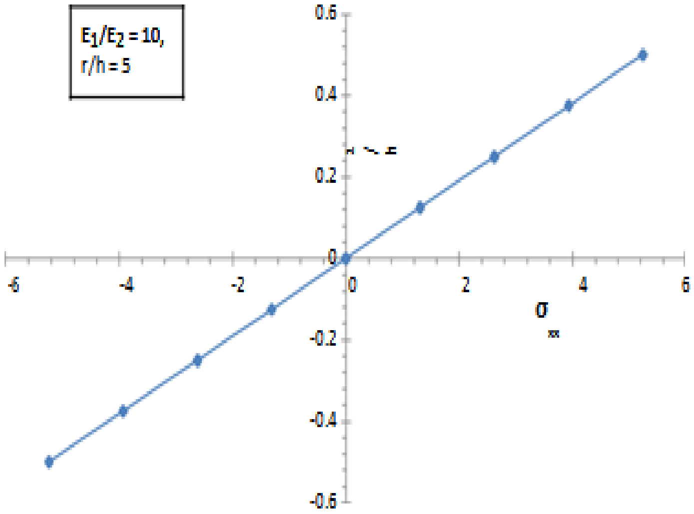

Fig. 4.2 Variation of stress in X-direction (σ_{xx}) through thickness (z/h) under uniform pressure

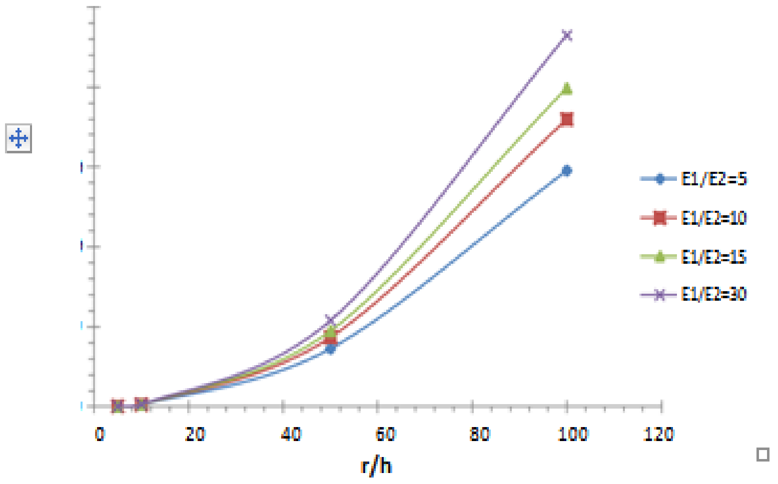

Figure 4.3 Variation of maximum stress under uniform pressure

CONCLUSION

In the present work, a four layered (□ 0/□ 0/□ 0/□ 0) clamped symmetric laminated circular plate with equal thickness of layers, under uniformly distributed load and central point load have been analyzed through the finite element technique using ANSYS. The material taken is E-epoxy[11] glass fibers included in a matrix of nestropol-450 unsaturated polyester resin and its properties used are as follows:

E1 = 39000 N/mm2, E2 = E3 = 8600 N/mm2,
G12 = G23 = G13 = 3800 N/mm2, □ 12 = □ 13 = 0.25 and □ 23 = 0.42

- The uniform pressure (q) and central point load (P) are taken 0.2 N/mm2 and 10 N respectively for analysis in the present work. Results of the present studies bring out the following conclusions:
- Variation of maximum stresses (σxx, σyy, τxy, τxz, τyz) and maximum radial stresses (σr, σϴ, rϴ) through thickness (z/h) of laminate by keeping θ = 00.
- Effect of modular ratio (e1/e2) 5, 10, 15 and 30 on central deflection (w), maximum stresses (σxx, σyy, τxy, τxz, τyz) and maximum radial stresses (σr, σϴ, rϴ) of circular plate for radius-to-thickness ratio (r/h) 5, 10, 50 and 100 by keeping θ = 00.
- Effect of lamina orientation on central deflection (w), maximum stresses (σxx, σyy, τxy, τxz, τyz) and maximum radial stresses (σr, σϴ, rϴ) for circular plate keeping, e1/e2 = 5, r/h = 5.

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