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Effects of In-Plane Shear Loads on Transverse Shear Deformations in Composite Panels

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An analytical and experimental investigation is performed to clarify the transverse shear deformations that occur in laminated and sandwich composite plates subjected to in-plane shear loads. This is part of a larger study investigating the feasibility of an in-plane shear test as a practical procedure to determine the in-plane shear modulus and/or strength of various material systems as well as the faces and cores of sandwich plates. The theorem of minimum potential energy has been used to determine the deflections and strains in the plate, including the transverse shear deformation effects. Polynomial functions that satisfy all the boundary conditions of the material system are used as trial functions. Comparison of these solutions to those first proposed by Nadai in 1925 revealed that additional terms are added to the original analysis (which used classical plate theory) to incorporate these effects. The methods developed clearly show the effects of the transverse shear deformation and are valid for any sandwich, laminate, or monocoque plate of any aspect ratio. Subsequent finite element and experimental analysis were conducted to verify the analytical study. Both the numerical and experimental results confirm that the analytical results are very good approximations for describing the linear deformation of the panels subject to in-plane shear loads.

I. Introduction

WITH the rapidly increasing use of composite materials over the world, fast, accurate, and inexpensive testing procedures for determining mechanical properties are needed. This goal is crucial for the design and optimization of advanced, complex composite structures. The in-plane shear test described herein appears to be a promising method to determine the in-plane shear modulus and strength of the composite materials used in laminated and sandwich panels. Figure 1 shows the loading condition of a rectangular plate for determining the in-plane shear strength and stiffness. In this configuration, loads of equal magnitude and direction are applied to two diagonal corners of the plate, and reacted at the two opposite corners.

The concept of an in-plane shear test for isotropic plates was first suggested by Nadai [1] in 1925. He solved the problem in an analytical way by finding a solution to the governing partial differential equations, which are derived from classical continuum mechanics. Recently, Vinson [2] derived a very simple expression to determine the in-plane shear strength of the composite materials in laminated and sandwich structures using the minimum potential energy method. As a special case, Vinson provided the equations for the in-plane shear strength of the face material, the core material, and the adhesive bond between the faces and the core for sandwich plate structures. Motivated by this analysis, Ebrahimpour et al. [3] conducted an experimental and numerical study to characterize the behavior of foam core sandwich composite plates subjected to in-plane shear loads.

This study described herein presents a solution including transverse shear deformation effects for this problem. The investigation of the transverse shear deformation effects is essential to better understand the behavior of the composite structures under the in-plane shear loading, especially for those plates having low transverse shear moduli G_{13} and G_{23}. This analysis follows the same methodology used by Vinson [2] and Wang et al. [4]. Numerical and experimental studies are used to verify the analytical conclusions. The primary motivation is to investigate the suitability of the in-plane shear test for improved manufacturing quality control of laminated and sandwich composite plates.

II. Analysis

Linear thin plate theories are assumed for the plates considered in this study; specifically, the thickness of the plate is much smaller than the other dimensions of the plate, and the plate experiences small lateral deflections. In the analysis that follows, all of the plates including isotropic, laminated, and sandwich structures are rectangular with no restriction of the aspect ratio. All surfaces are load free, and all composite plates are midplane symmetric and are specially orthotropic, that is, no 16 and 26 terms in the constitutive equations.

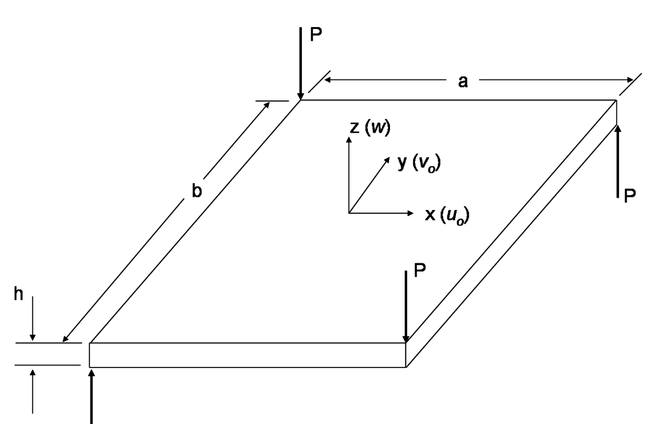

Fig. 1 Plate configuration and loading for the in-plane shear test.

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