Civil Engineering Faculty, TRANSILVANIA University of Braşov

BOOK OF ABSTRACTS

11th Youth Symposium on Experimental Solid Mechanics

30th of May 2012 ÷ 2nd of June 2012, Braşov, Romania

EDITURA UNIVERSITĂȚII *TRANSILVANIA* DIN BRAŞOV
TRANSILVANIA UNIVERSITY PUBLISHING HOUSE BRAŞOV

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Toate drepturile rezervate

Editură acreditată de CNCSIS
Adresa nr.1615 din 29 mai 2002

References: **Conf. univ. dr. ing. Horațiu TEODORESCU-DRĂGHICESCU**
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ISBN 978-606-19-0079-4

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FREE VIBRATIONS OF LAMINATED COMPOSITE PLATES USING LAYERWISE DISPLACEMENT MODEL

M. CETKOVIC[1] **DJ. VUKSANOVIC**[1]

1. Introduction

The accuracy in obtaining free vibration frequencies of composite plates is closely related to the assumed shear deformation pattern. It has been shown that Equivalent Single Layer (ESL**)** theories yield good predictions when materials properties of adjacent layers do not differ significantly. However, since they use continuously differentiable function of thickness coordinate, they are unable to account for severe discontinuities in transverse shear strains that occur at the interfaces between the layers with drastically different stiffness properties. In these cases, the local deformations and stresses, and sometimes even the overall laminate response, such as fundamental frequencies are not well predicted. In wish to overcome the shortcomings of ESL theories, and reduce the computational cost of 3D elasticity theory, discrete layer or layer wise (LW) theories have been proposed.

In this paper a discrete layer theory called Generalize Layerwise Plate Theory (GLPT) of Reddy is used to study free vibrations of laminated composite and sandwich plates. The objective of this paper is to code a MATLAB computer program for FEM solutions based on GLPT, capable of calculating fundamental frequencies of laminated composite and sandwich plates. The accuracy of computer program will be verified by comparison with available results from the literature.

2. Theoretical formulation

Mathematical model for free vibration of composite plate is formulated using the following assumed displacements field:

$$u_1(x,y,z) = u(x,y) + \sum_{I=1}^{N} U^I(x,y) \cdot \Phi^I(z),$$

$$u_2(x,y,z) = v(x,y) + \sum_{I=1}^{N} V^I(x,y) \cdot \Phi^I(z),$$

$$u_3(x,y,z) = w(x,y)\,. \tag{1}$$

where (u,v,w) are the displacements of a point $(x,y,0)$ on the reference plane of the laminate, U^I and V^I are undetermined coefficients, and $\Phi^I(z)$ are layerwise continuous functions of the thickness coordinate [1].

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3. Finite Element Model

Substituting assumed displacement field into virtual work statement the finite element model is obtained [1]:

$$[\mathbf{M}]^e\{\ddot{\boldsymbol{\Delta}}\}^e + [\mathbf{K}]^e\{\boldsymbol{\Delta}\}^e = 0 \qquad (2)$$

where element stiffness and element mass matrix are given in [2].

4. Numerical results and discussion

4.1 Example of sandwich plate

A five layer (0/90/core/0/90) symmetric simply supported sandwich plate is analyzed in the following example:

Face sheets (Graphite-Epoxy T300/934):

$$E_1 = 131\,GPa,\ E_2 = E_3 = 10.34\,GPa,$$
$$G_{12} = G_{23} = 6.895\,GPa,\ G_{13} = 6.205\,GPa,$$
$$\nu_{12} = \nu_{13} = 0.22,\ \nu_{23} = 0.49,\ \rho = 1627 kg/m^3$$

Core (Isotropic):

$$E_1 = E_2 = E_3 = 6.89x10^{-3}\ GPa,$$
$$G_{12} = G_{23} = G_{13} = 3.45x10^{-3}\ GPa,$$
$$\nu_{12} = \nu_{13} = \nu_{23} = 0,\ \rho = 97 kg/m^3$$

Free vibrations are normalized in the form:

$$\overline{\omega} = \omega\, b^2 / h \sqrt{(\rho / E_2)_f} \qquad (3)$$

The results on Figure 1 imply that ESL theories are unable to accurately predict fundamental frequencies of soft-core sandwich plates, since their assumed displacement field can not account for significant change of materials properties between adjacent layers.

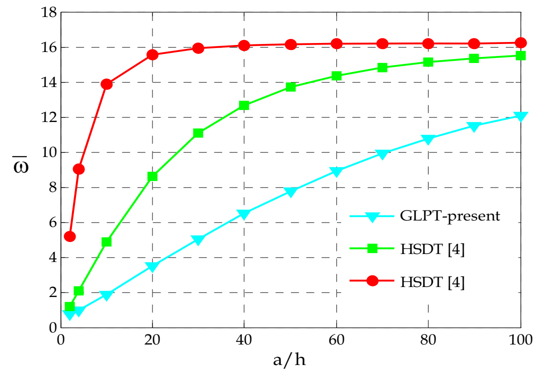

Fig. 1. *Fundamental frequencies of thin and thin sandwich plates*

5. Conclusions

In this paper the finite element solutions are presented for free vibration analysis of laminated composite and sandwich plates. The study has verified that the proposed model is capable to accurately predict fundamental frequencies of both thin and thick sandwich plates and may be used as the guideline for their optimal design in the laboratory.

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