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Free Vibration Analysis of Laminated Composite Box Sections

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***Abstract*— Laminated composite box sections may be subjected to vibrations. Their thin walled configuration makes them more prone to damages during such conditions. In the present paper, the free vibration characteristics of laminated composite box sections are studied and a design parameter is proposed. Finite Element Software ANSYS 15 is used for the purpose and natural frequencies determined. The variation of natural frequency with the proposed design parameter is studied.**

Keywords*— Laminated composites, Box section, Free vibration, Orthotropic Stiffness, Natural frequency

I. INTRODUCTION

Laminated composites consist of layers of fibrous composite materials. The individual layers consist of high modulus, high strength fibers in a polymeric, metallic or ceramic matrix material. They may or may not exhibit the properties of individual components. However, they are found to be stronger, lighter and more efficient than their individual counterparts. The major advantage is that they can be tailored as per requirement to achieve maximum performance. They find applications in automobile, aerospace, civil, mechanical and athletics industry. Their popularity is also evident in structural applications such as long span bridge decks, ship deck hulls and superstructure of offshore oil platforms. They are found to exhibit high strength to weight and stiffness to weight ratios, long fatigue life and excellent corrosion resistance. Some typical examples include carbon fiber epoxy, graphite epoxy and boron epoxies.

Thin walled laminated composite box sections used in bridges, ship decks, helicopter blades and other applications are subjected to vibrations. Since they are thin structures they are more vulnerable to these effects and hence there is a need to understand the vibration characteristics and need to identify criteria to design sections which are more effective against vibrations.

II. METHODOLOGY

Modelling of laminated composite box beams have been implemented using Finite Element Package ANSYS 15. ANSYS can carry out advanced engineering analyses quickly, safely and practically by variety of contact algorithms. Modelling of laminated composite box sections requires defining the properties of laminated composite, number of layers, thickness of laminate, type of layup and fiber orientations. Element used is Shell 281, with 8 nodes and 6 degrees of freedom at each node, preferred for modelling thin plates and shells.

A. *Orthotropic Stiffness Parameter*

Vibration characteristic is highly influenced by the stiffness of the laminated composite box section which in turn depends on the fiber orientation of the layers. Several arbitrary layup configurations were considered. Their stiffness evaluated and layups with constant values of extension stiffness A_{12} were chosen. A design parameter was able to be identified, referred in this paper as the Orthotropic Stiffness parameter. Close examination of various arbitrary layups and their stiffness helped in identifying this parameter. Further, study of this parameter and its variation with natural frequency was carried out.

Orthotropic Stiffness Parameter, C

$$= 1/2 \{(A_{11}/A_{66})_{web} + (A_{11}/A_{66})_{flange}\}$$

B. *Finite Element Modelling*

Laminated composite box section of Graphite Epoxy material is modelled. The material and geometric properties are as in Table 1.The layup considered is symmetric with angle combinations of angles 0·, 15·, 30·, 45·, 60·, 75· and 90· The model was analyzed for same lay up configuration in web and flanges. A total of 27 lay up configurations were considered for the study. A 3-D finite element model of the laminated composite box beam is developed in ANSYS 15 as in Figure 1.

C. *Free Vibration Analysis*

Natural frequency is the frequency at which a system tends to oscillate in the absence of any driving or damping force. Modal Analysis is carried out in ANSYS 15 to determine natural frequencies. The laminated composite box section of 4000 mm X 300 mm X 200 mm and 2mm thickness consisting of 6 layers were analyzed for about 27 layup configurations. The layup configurations were chosen such that their A_{12} is constant.

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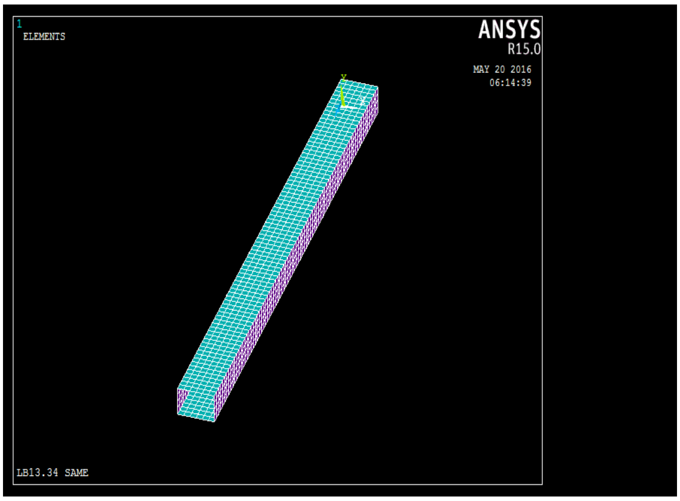

Fig 1 The 3 D Laminated Composite Box Section from ANSYS 15

III. RESULTS

For the box section of graphite epoxy material with geometric properties as in Table 1, orthotropic stiffness parameter is evaluated. First lowest natural frequency is also determined. This is done for sections, with same layup in web and flange.

From Table 2, it can be seen that lowest natural frequency is attained for an A_{12} value of 27337.9377, with orthotropic stiffness parameter value of 1.3132. This stands out to be 12.652 Hz. From Figure 2, it is evident that natural frequency reduces with reduction in orthotropic stiffness parameter.

TABLE 1. GEOMETRIC AND MATERIAL PROPERTIES

Material properties		Geometric properties	
Longitudinal modulus of elasticity, E_1(N/mm^2)	145000	Length (mm)	4000
Transverse modulus of elasticity, E_2(N/mm^2)	16500	Breadth (mm)	300
Longitudinal Poisson's ratio,υ_1	0.314	Depth (mm)	200
Transverse Poisson's ratio, υ_2	0.0357	Thickness (mm)	2
Shear Modulus, G (N/mm^2)	4480	Number of layers	6
Density, ρ (Kg/m^3)	1520	Ply thickness(mm)	0.33333

IV. CONCLUSION

A design parameter that help in proposing sections with least natural frequency was identified by studying stiffness of various layup configurations. The variation of this parameter with natural frequency was depicted.

- Design Parameter, called orthotropic stiffness parameter was identified.
- As Orthotropic stiffness parameter reduces natural frequency reduces, for sections of same lay up configurations in web and flange of box sections for a constant value of A_{12}.
- For any constant A_{12}, if orthotropic stiffness parameter is kept low then natural frequency can be reduced.

TABLE 2. RESULTS OF MODAL ANALYSIS

Sl no	Lay up	A_{12}	C	Natural frequency
1	[90/75/90]$_s$	16092.8931	2.30105808	13.169
2	[15/90/90]$_s$	16092.8931	7.44629879	20.277
3	[0/75/90]$_s$	16092.8931	8.24227029	24.465
4	[0/15/90]$_s$	16092.8931	13.387511	28.442
5	[75/0/0]$_s$	16092.8931	14.1834825	31.074
6	[75/75/75]$_s$	27337.9377	1.31322701	12.652
7	[90/60/90]$_s$	27337.9377	1.47772398	13.435
8	[60/90/0]$_s$	27337.9377	4.83219634	24.892
9	[0/30/90]$_s$	27337.9377	6.50943252	26.319
10	[60/0/0]$_s$	27337.9377	8.18666870	31.569
11	[60/90/75]$_s$	32960.4601	1.21930111	13.361
12	[45/90/90]$_s$	32960.4601	1.72345957	14.274
13	[90/60/15]$_s$	32960.4601	3.60500458	21.313
14	[0/60/75]$_s$	32960.4601	3.97407420	24.562
15	[0/45/90]$_s$	32960.4601	4.47823266	25.345
16	[0/75/30]$_s$	32960.4601	5.35146074	26.925
17	[60/60/90]$_s$	44205.5047	1.00615477	13.212
18	[75/75/45]$_s$	44205.5047	1.27801883	14.743
19	[90/60/30]$_s$	44205.5047	2.02076524	16.84
20	[60/60/0]$_s$	44205.5047	3.03537571	24.312
21	[30/60/0]$_s$	44205.5047	4.04998617	26.737
22	[75/60/60]$_s$	49828.0271	0.89282117	12.901
23	[90/60/45]$_s$	49828.0271	1.22097924	14.175
24	[75/60/30]$_s$	49828.0271	1.78936569	17.272
25	[75/30/30]$_s$	49828.0271	2.68591021	18.045
26	[60/30/15]$_s$	49828.0271	3.34222635	22.112
27	[0/45/30]$_s$	49828.0271	3.91061279	25.982

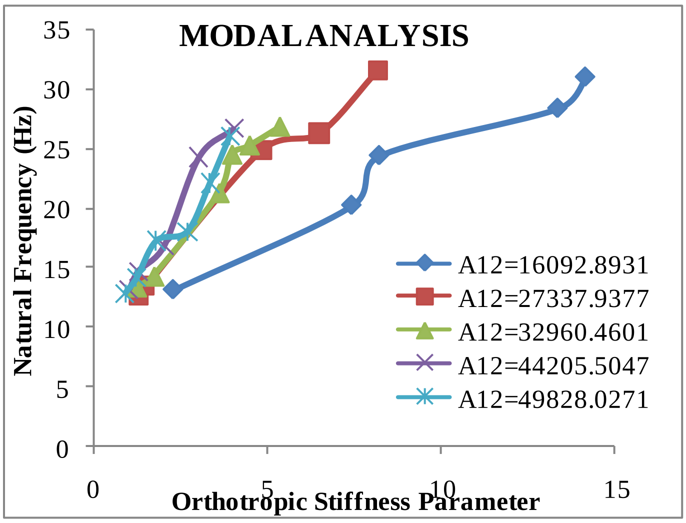

Fig 2. The variation of Orthotropic Stiffness and Natural Frequencies for various values of A_{12}

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