Study of Stresses and Deformations in Sandwich Plates with Anisotropic Facings

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Theme

THIS paper deals with the determination of the stresses and deformations in a sandwich plate with generally orthotropic facings and an isotropic core subjected to a uniform static lateral load.

A numerical study of the effect of facing anisotropy on the stress and strain components and on the core and facing strain energies is carried out. It is shown how the introduction of facing anisotropy affects both the magnitude and distribution of stresses and strains and how the core strain energy may be widely altered by varying the elastic axes of the facing material.

Contents

Several papers have appeared in the literature dealing with anisotropic plate and shell structure analysis. Among the more recent of these are papers by Ashton,[1] Whitney and Leissa[2] and Whitney and Pagano.[3] None of these, however, contains information concerning the effect of anisotropy on the distribution of stresses, strains and displacements within the structure.

For this study, governing equation derived by Kingsbury and Pavacic[4] for sandwich plates with thin anisotropic facings are used. These equations were derived using the usual assumptions of sandwich plate theory,[5] with the exception that the membrane facings are constructed from a generally orthotropic rather than isotropic material. The angle θ, between the plate edges (x, y) and the facing principal elastic axes (α, β) then serves as a convenient parameter for defining facing anisotropy.

The sandwich plate consists of upper and lower facings of thickness t and a core of thickness h. The plate has widths a and b with x, y directions, respectively.

The inplane displacement components u and v, and transverse displacement w at any point in the structure are given by $u = u_0(x, y) + \zeta(x, y)z$, $v = v_0(x, y) + \xi(x, y)z$, $w = w(x, y)$ where ζ and ξ are the rotation components of normals to the middle surface in the x-z and y-z planes.

The plate is simply supported on all edges and each of the facings are constructed of the same orthotropic material and have the same thickness. The material and geometric parameters used are listed below

$$E_\alpha = 40 \times 10^6\text{psi} \qquad E_\alpha/G_c = 200$$
$$E_\alpha/E_\beta = 10 \qquad \nu_{\alpha\beta} = 0.25$$
$$E_\alpha/G_{\alpha\beta} = 40 \qquad \nu_c = 0.3$$
$$t/h = 0.01 \qquad h/a = 0.02 \qquad a/b = 1.00$$

G_c and ν_c are the core material shear modules and Poisson's ratio while $E_\alpha . E_\beta$, $G_{\alpha\beta}$ and $\nu_{\alpha\beta}$ are the facing orthotropic elastic constants.

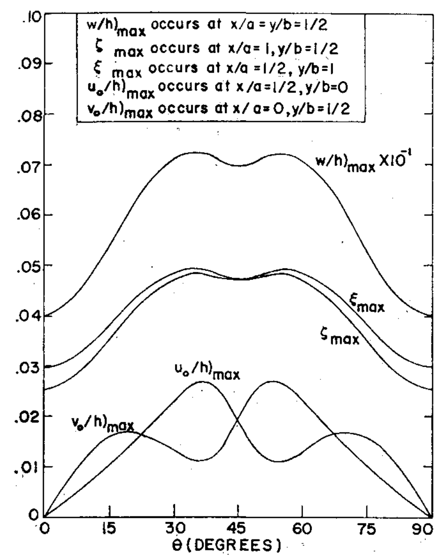

Fig. 1 Effect of θ on displacement and rotation variables.

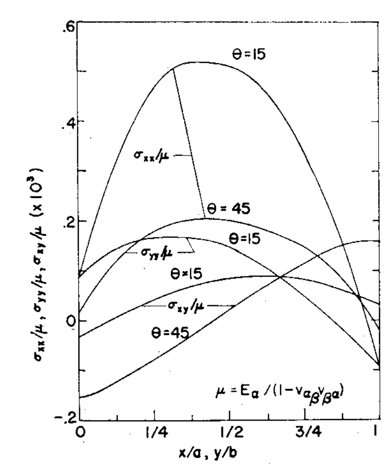

Fig. 2 Effect of θ on facing stress distribution.

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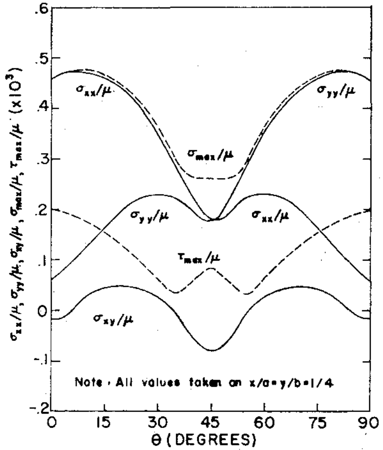

Fig. 3 Effect of θ on facing stress components at a point.

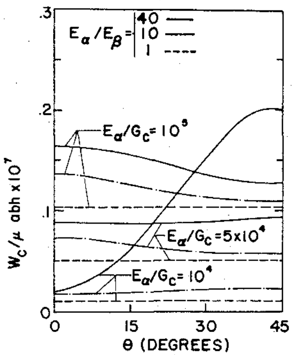

Fig. 4 Core strain energy vs θ.

The effect of θ on the magnitudes of the five displacement and rotation variables is shown in Fig. 1. Maxima occur in all curves in the interval $30°\langle\theta\rangle 35°$ or $55°\langle\theta\rangle 60°$ This is due to the asymmetric behavior of the elastic coefficients which represent shear-extension facing deformation coupling.

The plots of the various inplane facing stresses vs x and y do change shape as well as magnitude with θ as seen in Fig. 2. To give an indication of the effect of θ on the stresses, a point on the plate was chosen arbitrarily and the stresses plotted against θ in Fig. 3.

Figure 4 illustrates the effect of core shear modulus and facing elastic constant ratio as well as θ on core strain energy (W_c). For $E_\alpha = E_\beta$, W_c is unaffected by θ. Generally, G_c has more effect than E_β or W_c.

It appears that the core strain energy can be made large in two ways. Either specify a stiff core and very thin, highly anisotropic facings with $\theta = 45°$ which gives maximum deflections w or a very weak core can be chosen along with a thin, highly orthotropic facing, i.e., $\theta = 0°$. This gives a smaller w.

In conclusion, it is seen that the internal distribution of stress and stain is greatly affected by facing anisotropy. Of particular interest perhaps, is the many fold increase in facing maximum principal stress which implies that facing stability should be carefully examined in such structures. Also of note is the possibility of tailoring structural damping in a sandwich plate with a visco elastic core by judgeous choice of facing elastic modulus and orientation.

References

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