

TENSILE PROPERTIES ANALYSIS OF HONEYCOMB STRUCTURES

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Abstract: An analysis of honeycomb structures mechanical properties is presented. The honeycomb sandwich construction is one of the structural engineering developed and used in aerospace industry. The honeycomb sandwich structures provide the benefits over conventional materials: very low weight, high stiffness, durability and production cost savings. The finite element method is applied for the determination of the elastic characteristics of the sandwich structure with honeycomb core, in terms of constraints, loads and displacements.

Keywords: sandwich structures, honeycomb core, finite element analysis, elastic constants.

1. INTRODUCTION

The most important part of the aeronautical structures, the helicopter main rotor blade, can use exclusively composite materials. The most frequent solution is that of the sandwich structure with a core made of a very light material, in which the external surfaces have high strength limit. One of the most frequently used structures for the core is the honeycomb structure. Therefore, this paper present the applications of the finite element method for the determination of the elastic characteristics of the sandwich structure made of Dural boards and honeycomb core.

In figure 1, a honeycomb core is presented, the materials used being aluminum, paper or carbon fiber, depending on the pressures to which the sandwich structure is subjected.

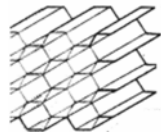


Fig. 1 Honeycomb structure

2. ANALYSIS

2.1 Honeycomb structure characteristics.

The honeycomb structure will be considered

an orthotropic material, which requires the elastic constants: Young's modulus, E_x , in x direction; E_y , in y direction, E_z , in z direction; $\nu_{i,j}$, Poisson's ratio ($i, j = x, y, z$), and shearing modulus G_{xy} , G_{yz} , G_{xz} .

Hooke's law generalized and detailed for an orthotropic material in relation with its axes has the following expression:

$$\begin{cases} \varepsilon_x = \frac{1}{E_x} \sigma_x - \frac{\nu_{yx}}{E_y} \sigma_y - \frac{\nu_{zx}}{E_z} \sigma_z \\ \varepsilon_y = -\frac{\nu_{xy}}{E_x} \sigma_x + \frac{1}{E_y} \sigma_y - \frac{\nu_{zy}}{E_z} \sigma_z \\ \varepsilon_z = -\frac{\nu_{xz}}{E_x} \sigma_x - \frac{\nu_{yz}}{E_y} \sigma_y + \frac{1}{E_z} \sigma_z \end{cases} \quad (1)$$

$$\gamma_{xy} = \frac{\tau_{xy}}{G_{xy}}; \gamma_{yz} = \frac{\tau_{yz}}{G_{yz}}; \gamma_{zx} = \frac{\tau_{zx}}{G_{zx}} \quad (2)$$

The following conditions are met:

$$\frac{\nu_{xy}}{E_x} = \frac{\nu_{yx}}{E_y}, \frac{\nu_{yz}}{E_y} = \frac{\nu_{zy}}{E_z}, \frac{\nu_{zx}}{E_z} = \frac{\nu_{xz}}{E_x}; \quad (3)$$

2.2 Analysis steps. The steps for finite element analysis are: identification of the representative unit cell for the whole honeycomb structure, meshing and applying

the boundary conditions, computation and processing the results.

The cell of the structure is a hexagonal cell and with this hexagonal cell it is possible to describe the entire honeycomb core, using the periodicity of the structure.

For the finite elements model, it is developed only one portion of the hexagonal cell unit of the honeycomb structure. By multiplying this portion in relation with O_x and O_y axes, one may notice that a real honeycomb structure is obtained. This portion will then be replaced in the final model by a solid element having the same elastic and weight characteristics.

A tri-dimensional element SOLID, presented in figure 2, is used in problems of structural analysis or thermal transfer. For the structural analysis, each node has three degrees of liberty, translations.

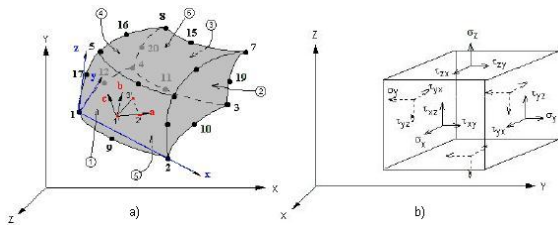


Fig. 2 SOLID element with 20 nodes

Mention should be made that the two types of elements previously presented are not perfectly compatible due to the different degrees of liberty of the nodes, that is, rotational degrees of liberty. The COSMOS/M program allows for the continuity control between the solid elements such as TETRA5, TETRA10 and SOLID and the diaphragm ones (SHELL). Some restrictions are necessary in terms of coupling and connecting these incompatible elements by using an indicator for rigid links. This allows for an articulate link (HINGE) between the solid and diaphragm elements that has to be stabilized by applying sufficient frontier conditions.

The developed analysis for the determination of the Young's modulus and Poisson's ratio, are the traction along the X axis, along the Y axis and along the Z axis. Once the structure is meshed, boundary

conditions are applied on the structure in terms of constraints, loads and displacements.

Figure 3 presents the geometrical characteristics of the unit cell portion developed from the hexagonal honeycomb structure.

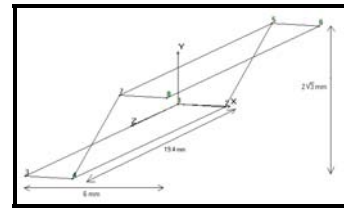


Fig. 3 Geometrical characteristics of the developed honeycomb structure sample

2.3 Axial load. The boundary conditions along the axis are presented in table 1, and figure 4.

Table 1 Boundary conditions

Displacement		Node							
		1	2	3	4	5	6	7	8
Traction along X axis	Along X axis	0	/	0	/	/	0.1	/	0.1
	Along Y axis	0	0	0	0	0	0	0	0
	Along Z axis	0	0	0	0	/	/	/	/
Traction along Y axis	Along X axis	0	/	0	/	/	0	/	0
	Along Y axis	0	0	0	0	0.05	0.05	0.05	0.05
	Along Z axis	0	0	/	/	0	0	/	/
Traction along Z axis	Along X axis	0	/	0	/	/	0.1	/	0.1
	Along Y axis	0	0	0	0	0	0	0	0
	Along Z axis	0	0	0	0	/	/	/	/

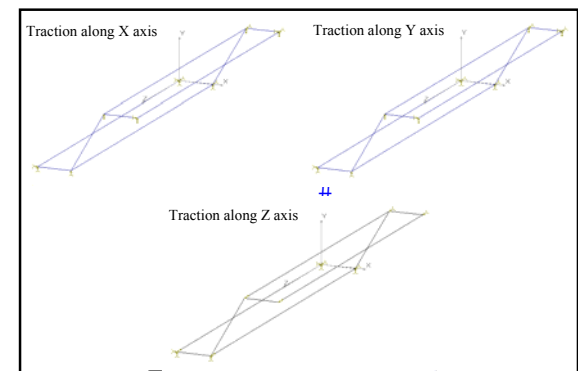


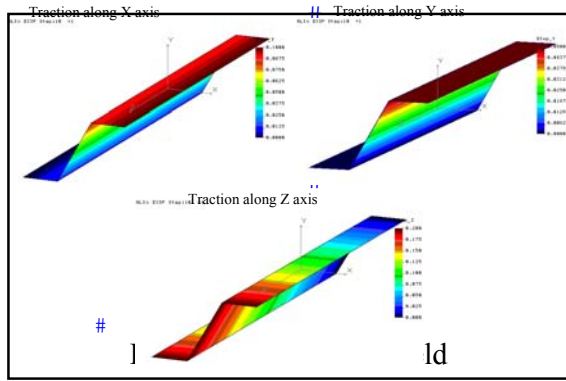
Fig. 4 Boundary conditions

2.4 Results. The obtained results are presented in table 2, whereas the

displacements along the axis are represented in figure 5.

Table 2 Results##

Results	Traction along X axis	Traction along Y axis	Traction along Z axis
Normal force along X axis, N _x (N)	267.8	222.3	0
Normal force along Y axis, N _y (N)	446.5	395.2	0
Normal force along Z axis, N _z (N)	0	0	219.81
Displacement along X axis, δ _x (mm)	0.1	0	-0.021033
Displacement along Y axis, δ _y (mm)	0	0.05	-0.012151
Displacement along Z axis, δ _z (mm)	-0.05066	-0.05335	0.2



Based on these results, one can calculate:

Traction along X axis

- normal stress on x axis:

$$\sigma_x = N_x / A_{yOz} \quad (4)$$

$$\sigma_x = 267.8 / (19.4 * 2.3) = 3.985 \text{MPa}$$

- normal stress on y axis:

$$\sigma_y = N_y / A_{xOz} \quad (5)$$

$$\sigma_y = 446.5 / (19.4 * 6) = 3.835 \text{MPa}$$

- normal stress on z axis:

$$\sigma_z = N_z / A_{xOy} \quad (6)$$

$$\sigma_z = 0 \text{MPa}$$

- strain on x axis:

$$\epsilon_x = \delta_x / l_x \quad (7)$$

$$\epsilon_x = 0.1 / 6 = 1.666 * 10^{-2}$$

- strain on y axis:

$$\epsilon_y = \delta_y / l_y \quad (8)$$

$$\epsilon_y = 0$$

- strain on z axis:

$$\epsilon_z = \delta_z / l_z \quad (9)$$

$$\epsilon_z = -0.05066 / 19.4 = -0.2611 * 10^{-2}$$

Substituting these results in equations (1)

we obtain the following system of equations:

$$\begin{cases} 0 = \frac{1}{E_x} 3.985 - \frac{\nu_{yx}}{E_y} 3.835 \\ 1.666 * 10^{-2} = -\frac{\nu_{xy}}{E_x} 3.985 + \frac{1}{E_y} 3.835 \quad (10) \\ -0.2611 * 10^{-2} = -\frac{\nu_{xz}}{E_x} 3.985 - \frac{\nu_{yz}}{E_y} 3.835 \end{cases}$$

Traction along Y axis

- normal stress on x axis:

$$\sigma_x = 222.3 / (19.4 * 2.3) = 3.308 \text{MPa}$$

- normal stress on y axis:

$$\sigma_y = 394.2 / (19.4 * 6) = 3.386 \text{MPa}$$

- normal stress on z axis:

$$\sigma_z = 0 \text{MPa}$$

- strain on x axis:

$$\epsilon_x = 0$$

- strain on y axis:

$$\epsilon_y = 0.05 / 2.3 = 1.4435 * 10^{-2}$$

- strain on z axis:

$$\epsilon_z = -0.05335 / 19.4 = -0.275 * 10^{-2}$$

Substituting these results in equations (1)

we obtain the following system of equations:

$$\begin{cases} 0 = \frac{1}{E_x} 3.308 - \frac{\nu_{yx}}{E_y} 3.386 \\ 1.4435 * 10^{-2} = -\frac{\nu_{xy}}{E_x} 3.308 + \frac{1}{E_y} 3.386 \quad (11) \\ -2.275 * 10^{-2} = -\frac{\nu_{xz}}{E_x} 3.308 - \frac{\nu_{yz}}{E_y} 3.386 \end{cases}$$

Traction along Z axis

- normal stress on x axis:

$$\sigma_x = 0 \text{MPa}$$

- normal stress on y axis:

$$\sigma_y = 0 \text{MPa}$$

- normal stress on z axis:

$$\sigma_z = 219.81 / (6 * 2.3) = 10.576 \text{MPa}$$

- strain on x axis:

$$\epsilon_x = -0.021033 / 6 = -0.3505 * 10^{-2}$$

- strain on y axis:

$$\varepsilon_y = -0.012151/2\sqrt{3} = -0.3507 * 10^{-2}$$

- strain on z axis:

$$\varepsilon_z = 0.2/19.4 = 1.0309 * 10^{-2}$$

Substituting these results in equations (1) we obtain the following system of equations:

$$\begin{cases} -0.3505 * 10^{-2} = -\frac{\nu_{zx}}{E_z} 10.576 \\ -0.3507 * 10^{-2} = -\frac{\nu_{zy}}{E_z} 10.576 \\ 1.0309 * 10^{-2} = \frac{1}{E_z} 10.576 \end{cases} \quad (12)$$

Solving the systems equations (10), (11), and (12), and considering equations (3), get the following results for longitudinal modulus of elasticity and Poisson's ratio:

$$E_x = 14.28 \text{ Pa}$$

$$E_y = 13.06 \text{ MPa}$$

$$E_z = 1043.92 \text{ MPa}$$

$$\nu_{xy}/E_x = 0.067$$

$$\nu_{yx}/E_y = 0.068$$

$$\nu_{yz}/E_y = 3.45 \cdot 10^{-4}$$

$$\nu_{zy}/E_z = 3.31 \cdot 10^{-4}$$

$$\nu_{xz}/E_x = 3.28 \cdot 10^{-4}$$

$$\nu_{zx}/E_z = 3.31 \cdot 10^{-4}$$

3. CONCLUSIONS

The finite elements method is the most effective method of numeric calculus in structure analysis, regardless of their type and complexity. By applying the constitutive law of an orthotropic material, only for the

reference orthotropy axes, the sample mechanical characteristics have been determined. Based on this work, an equivalent model will be developed, in a static and dynamic calculus of a sandwich structure. This method eliminates the disadvantages of analytical methods, and is successfully used to solve calculus problems related to aeronautical structures.

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