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EVALUATION OF THE INFLUENCE FOR THE COMPONENTS OF A MULTILAYERED HONEYCOMB COMPOSITE MATERIAL SUBJECTED TO COMPLEX STATIC LOADING

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Rezumat: *Scopul acestui articol este studiul influenței componentelor unui material compozit multistrat cu miez de tip fagure asupra modului de preluare a unei sarcini statice complexe, în domeniul liniar elastic. Pentru efectuarea acestui studiu s-a folosit simularea numerică, iar rezultatele obținute au fost validate prin cale experimentală.*

Abstract: *The purpose of these article is the evaluation of the influence of the components of a multilayered honeycomb composite material, about the load caring capacity, when the material is subjected to a complex static loading , in the linear elastic domain. The numerical simulation approach was used for these study, and the results were validated experimentally.*

Keywords: multilayered honeycomb structure components, numerical simulation, experimental validation

1. Introduction

Composite materials are used today in many high-tech engineering applications and they are the subject of intense research. One of the most used composite material classes are the honeycomb composite materials.

These composite materials have multiple advantages, the most important advantage of these materials is their low weight compared to the high strength. Due to their advanced mechanical properties, they are used in the most demanding areas of mechanical engineering. The lightweights and high-strength makes them ideal materials used in aerospace engineering. Aircraft and spacecraft structures are using honeycomb composite materials in the primary and secondary structural components, for example the outer hall of spacecraft structures is made of honeycomb composite materials. [1] [2]

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Today honeycomb composite materials are the subject of intense scientific research and development. The elastic properties of honeycomb structures depend on the materials used for the core and the cell geometrical dimensions [3], [4]. The primary load which is honeycomb composite material is subjected is compression, and bending. Also, it has been established that honeycomb composite materials are resistant materials, when they are subjected to impact loading. The main component which dictates the load carrying capacity of the honeycomb composite material subjected to impact loading is the core. It has been evaluated that for a honeycomb composite material subjected to impact loading the core distributes the impact energy on the honeycomb structure [5], [6].

In [16] is stated that in the bending test an Al honeycomb core is abruptly fractured without plastic deformation. The optimal energy absorption per unit volume is related to dynamic plateau stress and dynamic densification strain [15], thus that the dynamic densification strain determines the cushioning performance [14]. Also, the experimental investigation performed in [12] showed that under static loading, the composite sandwich failed with sudden brittle type failure due to shear failure of the core and compressive failure of the skins followed by debonding between the skin and the core.

In the recent decades, new honeycomb composite materials were developed using nonconventional honeycomb cores. Such materials present better mechanical properties compared to traditional honeycomb cores as well new types of mechanical properties. For some cases honeycomb course can possess negative Poisson ratio [7]. Such property allows the honeycomb structures to be used in new engineering applications.

The main purpose of this article is to evaluate the contribution of multilayered honeycomb composite material components, to its load carrying capacity, in the linear elastic domain of the material, using finite element simulation and experimental validation.

2. Material description

The multilayered honeycomb composite material is made of five layers: two honeycomb cores and three laminated single and double layered composites.

The two outer sheets are double layered woven composites. The core of the material is made of two honeycomb cores separated by woven composite laminate.

The single and double layered composite laminates are linked to the cores using polyester resign.

The multilayered honeycomb composite material is presented in figure 1. The honeycomb cores are impregnated in polyester resign.

Fig. 1. Multilayered honeycomb composite material.

3. Analysis description

In order to study the load carrying capacity and the influence of components on the multilayered honeycomb composite material, two sets of analysis will be carried out. In the first set the mechanical properties of the laminated composite materials will be considered isotopic. In the second set the elastic properties of the laminated composite materials will considered with orthotropic elastic properties. After completing the two analysis sets, the results will be compared, and to established the influence of the components of the multilayered honeycomb composite material.

To offer consistency of the results, prior to the finite element analysis, a static experimental test is carried out.

4. Experimental setup

The specimen of multilayered honeycomb composite material, which will be subjected to a combined static loading it is presented in figure 2.

Fig. 2. Multilayered honeycomb composite material specimen.

The dimensions of multilayered honeycomb composite material is presented in figure 3.

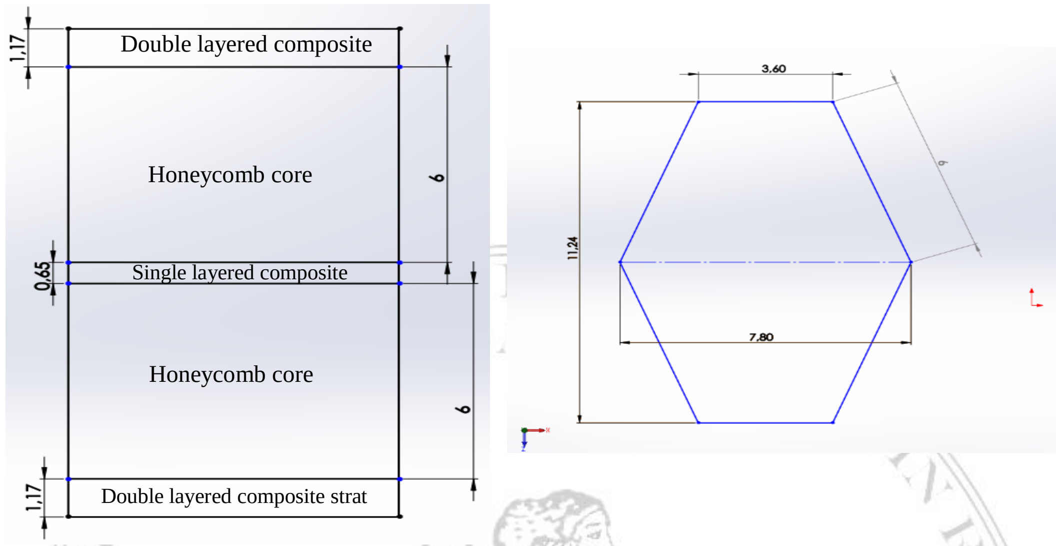

Fig. 3. Multilayered honeycomb composite material dimensions.

The thickness of cell walls is 0.55 mm.

The multilayered honeycomb composite material is placed on a support plate, dimension 60x60, with a hole in the center of 20 mm in diameter, figure 4. The multilayered honeycomb composite material is subjected to a combined loading by the displacement of a stamp.

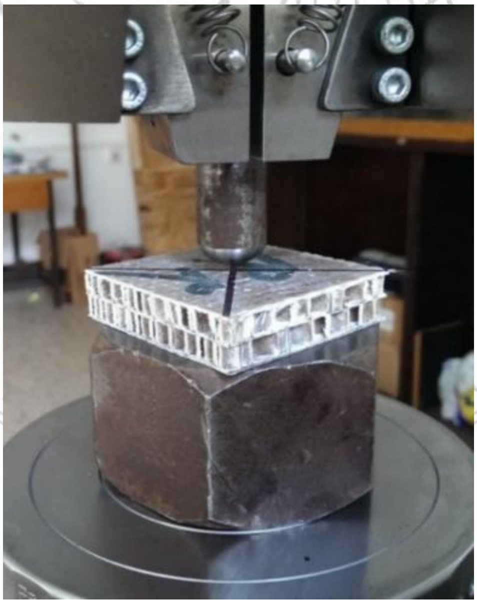

Fig. 4. Multilayered honeycomb composite material in test position.

After completing the static testing, the obtained results are presented in the figure 5.

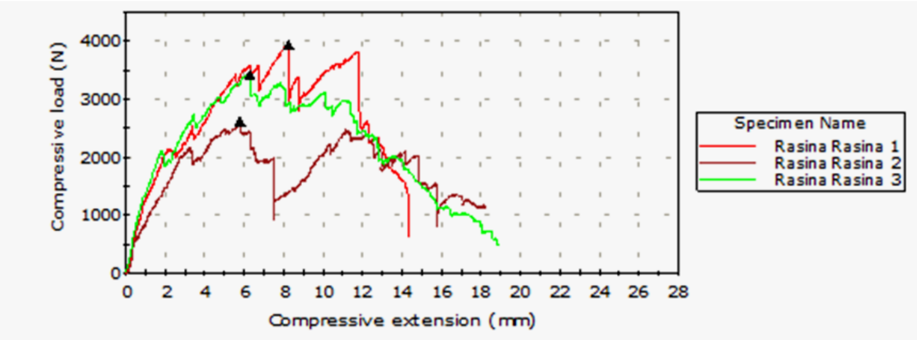

Fig. 5. Experimental test results.

5. Finite element and geometry description

The correlation between the effective properties of the single honeycomb core obtained by the analytical and numerical modelling is in good agreement as is stated in [13], thus a numerical approach is proposed. Because the relative position of the honeycomb cores can't be exactly determined, four geometrical models are considered, based on the position of the two honeycomb cores.

For the first geometrical model, the two honey comb cores are overlapping, figure 6.

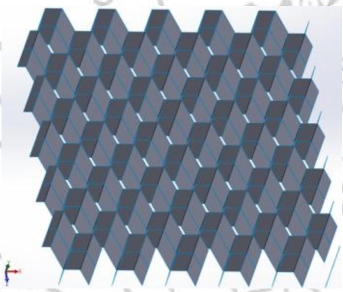

Fig. 6. First geometrical model [9].

For the second geometrical model the two honeycomb cores are displaced, from one another with 3.5 mm on the x-axis direction, figure 7.

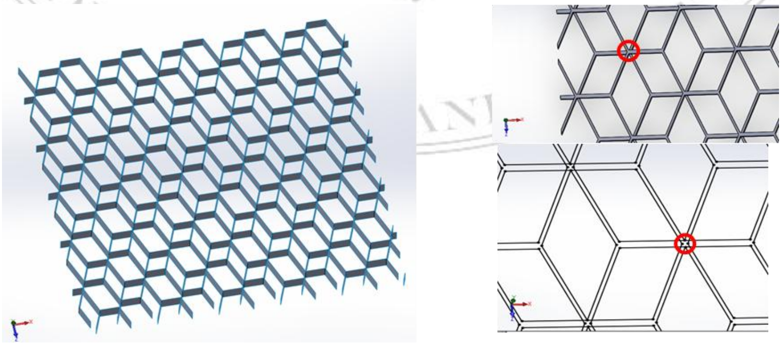

Fig. 7. Second geometrical model [9].

In the third case, the two honeycomb cores are displaced with a 5.6 mm on the z axis direction from one another, figure 8.

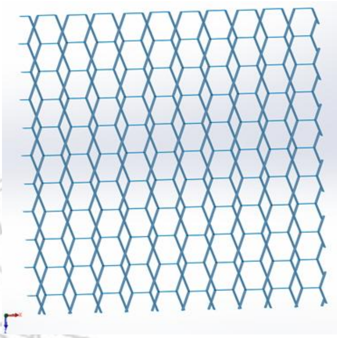

Fig. 8. Third geometrical model [9].

For the forth geometrical configuration, a combined displacement is considered, from the second and the third case, figure 9.

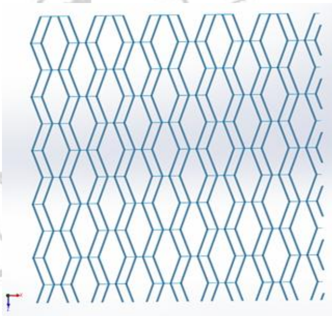

Fig. 9. Forth geometrical model [9]

The finite element model consists of three components: the stamp, the multilayered composite material and the support, figure 10.

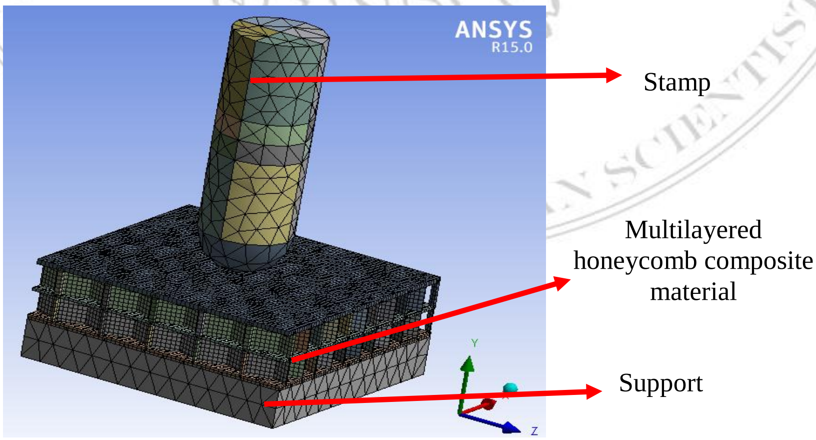

Fig. 10. Finite element model.

6. Computational conditions

For the finite element analysis, the support was articulated. Two frictionless contact definitions were made, one between the stamp and the upper double layered composite woven sheet and the other between the support and lower double layered composite sheet.

In the analysis, the multilayered honeycomb composite material, is subjected to a combined loading throw the displacement of the stamp. The reaction forces are taken for the given displacement of the stamp.

The reaction forces, obtained for all the four material configurations are mediated, for each given displacement.

7. Material properties

For the woven composite sheets, the elastic modulus, for both directions, was obtained throw tension tests. The other mechanical properties were taken from [11].

Table 1. Mechanical properties of woven composite material

Mechanical property	*Value*
Ex single layered	16664
Ey single layered	14054
Ex double layered	17244
Ey double layered	15314
E_z [11]	7122.9 [MPa]
ν_{xy} [11]	0.129
ν_{yz} [11]	0.109
ν_{zx} [11]	0.33
G_{xy} [11]	5942.3 [MPa]
G_{yz} [11]	5014.3 [MPa]
G_{zx} [11]	3138.5 [MPa]

Because the elastic modulus values for the two directions are similar, is possible to reduce the complexity of the model by mediating the values. The elastic modulus values considered in the computation are presented in table 2

Table 2. Material properties considered woven laminated composite

Mechanical property	*Value*
E_x	16954 [MPa]
E_y	14684 [MPa]

In the case of honeycomb walls, the Young modulus was determined identically, as in the case of the woven composite. The results are presented in table 3.

Table 3. Mechanical property of honeycomb cell

Mechanical property	*Value*
E	16357 [MPa]
ν [10]	0.35

Isotropic material properties were considered for the woven composite material by mediating the values of the mechanical properties. The values for the isotropic mechanical properties are presented in table 4.

Table 4. Isotropic material properties for the composites sheets

Component	*Young modulus* [MPa]	*Poisson ratio*
Woven composite	15819	0.33

For the support and stamp, standard steel elastic properties were used.

8. Analysis results

Table 5. Reaction forces values for the ortotropic computational set

Displacement [mm]	*Reaction Force* [N] Model 1	*Reaction Force* [N] Model 2	*Reaction Force* [N] Model 3	*Reaction Force* [N] Model 4	*Reaction Force Medium Value* [N]
0.00	0.00	0.00	0.00	0.00	0.00
0.50	536.97	541.46	904.03	571.30	638.44
1.00	1073.90	1082.90	1808.10	1142.60	1276.88
1.50	1610.90	1624.40	2712.10	1713.90	1915.33
2.00	2147.90	2165.80	3616.10	2285.20	2553.75
2.50	2684.90	2707.30	4520.10	2856.50	3192.20

Table 6. Reaction forces values for the isotrfopic computational set

Displacement [mm]	*Reaction Force* [N] Model 1	*Reaction Force* [N] Model 2	*Reaction Force* [N] Model 3	*Reaction Force* [N] Model 4	*Reaction Force Medium Value* [N]
0	0.00	0.00	0.00	0.00	0.00
0.5	520.69	524.54	877.00	548.66	617.72
1	1041.40	1049.10	1754.00	1097.30	1235.45
1.5	1562.10	1573.60	2631.00	1646.00	1853.18
2	2082.70	2098.10	3508.00	2194.60	2470.85
2.5	2603.40	2622.70	4385.00	2743.30	3088.60

The displacement values of the stamp, were taken for the linear elastic domain of the multilayered honeycomb composite material, five values were considered.

After completing the finite element analysis, for two computational sets, on each of the four geometrical models, the values of the obtained reaction forces are presented in tables 5 and 6.

To validate the finite element results, the reaction forces values are taken from the experimental results, for the given displacement, in the linear elastic domain of the multilayered honeycomb composite material. The result are presented graphically in the figure 11.

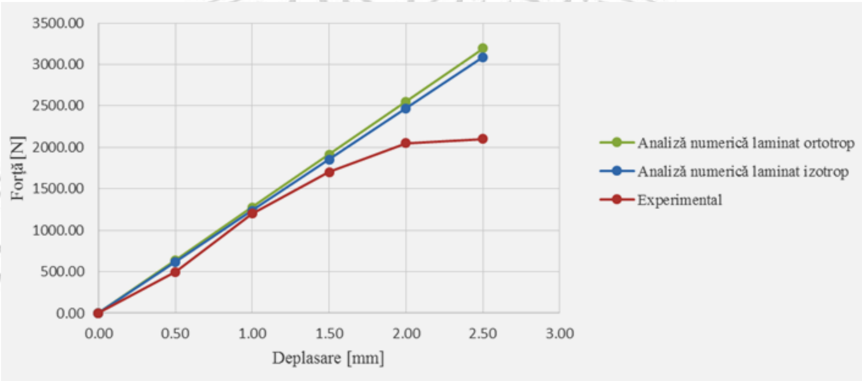

Fig. 11. Static response curves.

9. Conclusions

After completing the analysis, the following conclusions can be established:

1. To evaluate the influence of the components, of a multilayered honeycomb structure statically loaded, mainly finite element simulation has been carried out.

2. The finite element evaluation consisted of two sets of computations, one considering isotropic elastic properties for the woven composite material and the other considering the natural orthotropic elastic properties.

3. The result of the finite element simulation for the orthotropic woven composite were checked using the experimental approach.

4. The elastic properties for the isotropic woven composite were obtained by mediating the elastic properties of the orthotropic woven composite sheets.

5. The static response curves in the two computational sets are very similar, which suggest that the face sheets are not the main load caring components of the multilayered honeycomb composite material.

6. The results obtained for the finite element simulation are in good correspondence with the result obtained with the experimental testing. Thus the finite element model, used to study the behavior of multilayered honeycomb composite material, and all the assumptions made during the analysis were correct.

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