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Numerical evaluation of the behaviour of a multilayered honeycomb composite material in an aeronautical engineering application

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Abstract. The improvements made in the field of the research of composite materials led to the wide usage of composite materials, which, nowadays, tend to replace traditional metallic materials in engineering applications. In this paper, the performances of a landing gear, subjected to dynamic loadings and made of a multilayered honeycomb composite material are evaluated in comparison with traditional metallic materials using numerical simulation. The obtained values of mechanical stress for the hybrid landing gear design are lower compared to those for a landing gear made entirely of aluminium. The use of the multilayered honeycomb composite material decreases the values of the stresses, for the given load case. Also, reduction of the mass of the landing gear improves flight dinamics and increases manoeuvrability.

Keywords: multilayered honeycomb composite material, numerical simulation, landing gear.

1. Introduction

The result of the ongoing research in the field of composite materials, in the last decades, resulted in the development of new composite materials with improved mechanical properties. As a result, the composite materials tend to replace traditional metallic materials in engineering applications. The advantages of the composite materials, in comparison to the traditional metallic materials are: lower mass, a better dimensional stability, improved mechanical properties such as better resistance to static and dynamic loads [1].

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Among the multitude of composite materials, honeycomb composite materials are the subject of intense research and development in engineering applications. The mechanical behaviour of these materials is intensely studied [2], [3], [4]. These studies made possible the development of new types of honeycomb composite materials, with new mechanical properties, such as negative Poisson ratio, presented by Lakes [5].

Other studies made possible the analytical evaluation of the elastic properties of these materials [6], [7], [8].

These materials are used in the highest demanding fields of mechanical engineering such as: aeronautical, astronautical, naval and military. They are widely used in the primary and secondary aeronautical structures [9].

In 2007, Curtis proposed the use of honeycomb composite materials in armour structures [10].

Ryan, Riedel and Shafer [11] have studied the behaviour of honeycomb space structures subjected to ballistic impact loading. The buckling of honeycomb cell walls was studied using the numerical approach by Asprone et al. [12].

The main purpose of the study is the evaluation of the performances of a multilayered honeycomb composite material, in comparison with traditional metallic materials, subjected to low velocity impact loading, by means of numerical simulation.

The considered application is the landing gear of an ultralight aircraft. The mechanical behaviour of these material was intensely studied by the authors using experimental methods and finite element simulations [4], [13], [14].

2. Ultralight aircraft

Ultralight aircrafts are sports aircrafts, with the following performances:

- maximum flying speed: 300 - 350 km/h;
- maximum flying altitude: 4 - 5 km;
- maximum range: 90 - 900 km.

In figure 1 (a and b) are presented two ultralight aircrafts.

Fig. 1. *a.* Pterodactyl Ascender ultralight aircraft, mass 57 kg.

Fig. 1. *b.* Evektor SportStar ultralight aircraft, mass 600 kg.

Ultralight aircraft structures are lattice structures, made of aluminium.
The main components of the structure are: fuselage, landing gear, lifting surfaces and engine.
The landing gear of an ultralight aircraft, is a component which is subjected to bending loading due to impact load which occurs on landing.
Statistically, the duration of an impact loading which occurs at landing of an aircraft is 50-200 ms. The stress calculation in the landing gear is performed without taking into account the aerodynamic loads, due to the main purpose of this paper.

3. Description of the multilayered honeycomb composite material

The multilayered honeycomb composite material, created by the authors, is made out of five layers: two honeycomb core layers, made out of paper and impregnated in polyester resin, separated by a single layer of woven composite material, made of fiberglass, also impregnated in polyester resign and two outer face sheets made of double layered woven composite material (fig. 2) [4]. In the figure below, the geometrical dimensions of the composite material are presented.

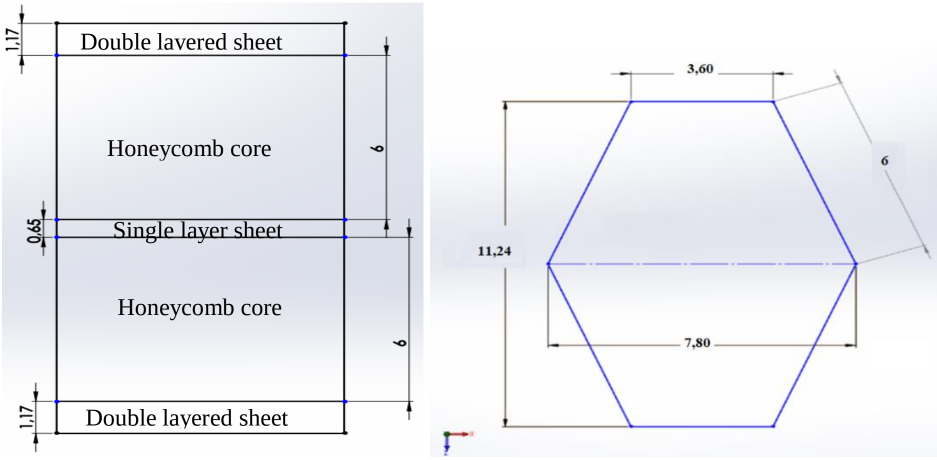


Fig. 2. Multilayered honeycomb composite material geometrical dimensions.

The multilayered composite materials (Fig. 3) was developed and studied in the University Politehnica of Bucharest, Faculty of Engineering and Management of Technological Systems, Department of Strength of Materials [4].

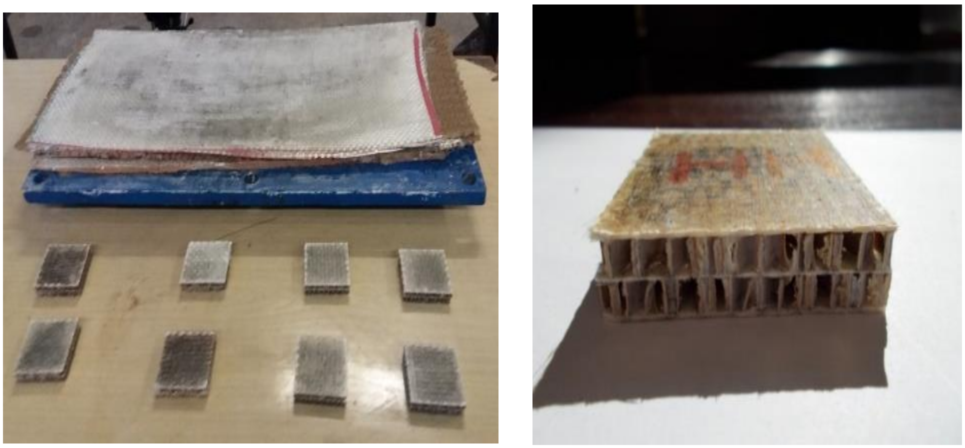


Fig. 3. Multilayered honeycomb composite material specimens.

The authors have studied the mechanical behaviour of the composite material subjected to low velocity impact loading, in the linear elastic domain of the material [3], [14]. The main purposes of these studies were: evaluation on the linear elastic domain of the composite material subjected low velocity by loadings, equivalation of the dynamic loading, in the linear elastic domain, with a static loading.

4. Geometrical model of the landing gear

To evaluate the mechanical performances of multilayered honeycomb composite material in comparison with the traditional metallic materials, subjected to low velocity impact loading, a numerical simulation was carried out on a landing gear. Two landing gears were considered: one made entirely of aluminium and the other made of aluminium and the multilayered honeycomb composite material, described above.

The geometry of the landing gear is presented in figure 4.

It can be observed that the geometrical model of the landing gear presents two planes of symmetry, thus it is sufficient to consider a quarter of the geometrical model in the numerical simulation (fig. 5).

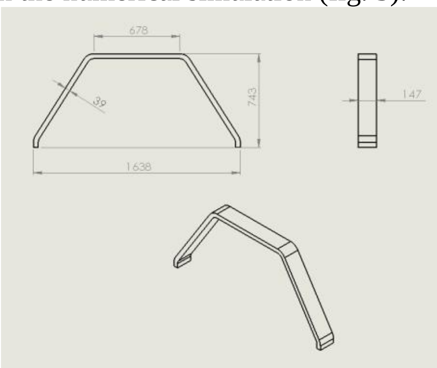


Fig. 4. Landing gear.

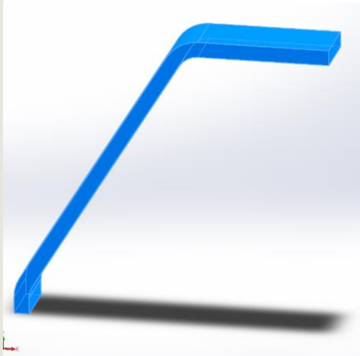


Fig. 5. Reduced geometrical model.

To take into account the mass of the aircraft and the pilot, an additional parallelepipedal geometry was considered, placed on the horizontal portion of the landing gear, as in figure 6.

The geometrical model of the hybrid landing gear, which contains the multilayered honeycomb composite material, is presented in figure 7. It can be observed that the composite material is placed on the horizontal portion of the landing gear.

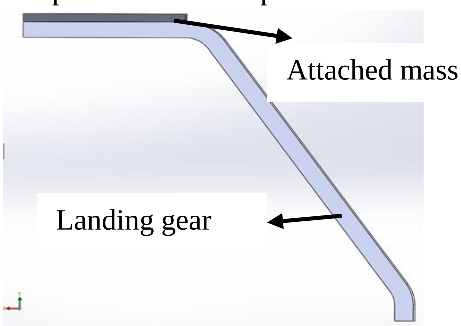


Fig. 6. Geometrical model of the landing gear with attached mass.

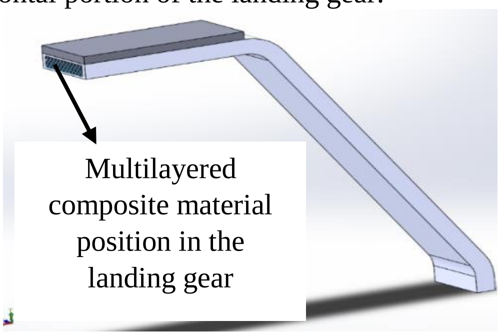


Fig. 7. Position of the composite material in the structure of the hybrid landing gear.

The elastic properties of the materials used in the simulation are presented in table 1.

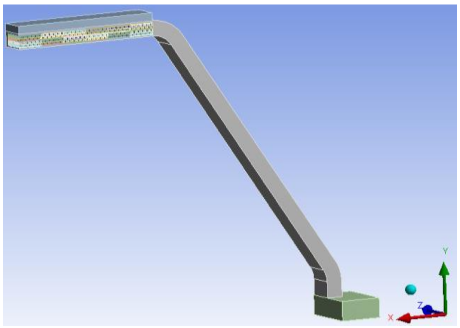
Table 1. Material elastic properties [3].

Component	Young modulus [MPa]	Poisson ratio [-]	Density [kg/m^3]
Laminated composite material	15819	0.33	1330
Aluminium	70000	0.27	2700
Honeycomb core	16357	0.35	1330

For the attached mass, a generic material, with the density of 69731 kg/m^3, was considered, in order to take into account the 150 kg total mass of the aircraft and pilot. Due to the double symmetry of the structure, only a quarter of the total attached mass is taken into consideration for the numerical simulation.

5. Numerical analysis of the landing gear

The behaviour of the analysed structure was studied, by numerical simulation of the landing gear’s response at the moment of impact using the ANSYS Explicit dynamics module. Four load cases defined by the landing vertical impact speed of the aircraft were studied. The impact speeds were: 1.2, 1.7, 2.1 and 3 m/s.
Analysis duration was set for a period of 50 ms. Also the curb weight of the landing gear and the gravitational acceleration were taken into account.
The finite element model (not shown in detail due to complicated geometry of the honeycomb core and limited space) was made using two types of finite elements, as follows: four-node and six-degree of freedom per node (three translations and three rotations) shell elements were used to model honeycomb cells, and for the modelling of the adjacent plates were used both solid elements with eight nodes and tetrahedral elements with four nodes having three degrees of freedom per node. Perfect coupling between plates and honeycomb cells (bonded), which is the ideal case for such a structure, was considered. Dynamic analysis was undertaken in the worst situation, when landing would occur on a rigid surface. Although this hypothesis does not correspond to reality, it is allowable and useful for our purpose, to compare the results for different materials. The size of the finite elements varied between one and five mm. The considered model led to 350000 equations.
To evaluate the performances of the composite material in comparison with the traditional metallic material, two finite element models were made for the two landing gears, presented in figure 8.



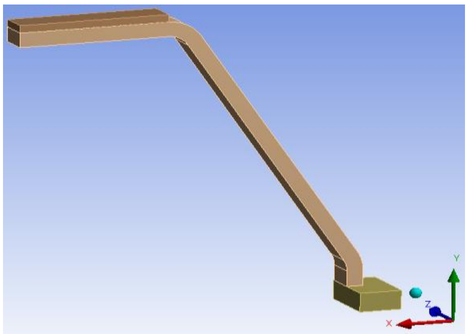


Fig. 8. *a.* Hybrid landing gear. Fig. 8. *b.* Aluminium landing gear.

The finite element models contain (fig. 9):
- quasi rigid support, with modified density, 37.5 kg mass;
- hybrid landing gear

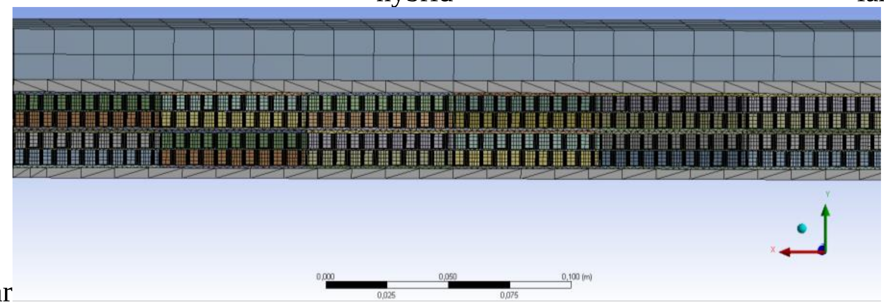


Fig. 9. Detailed view of the composite material in the structure of the hybrid landing gear.

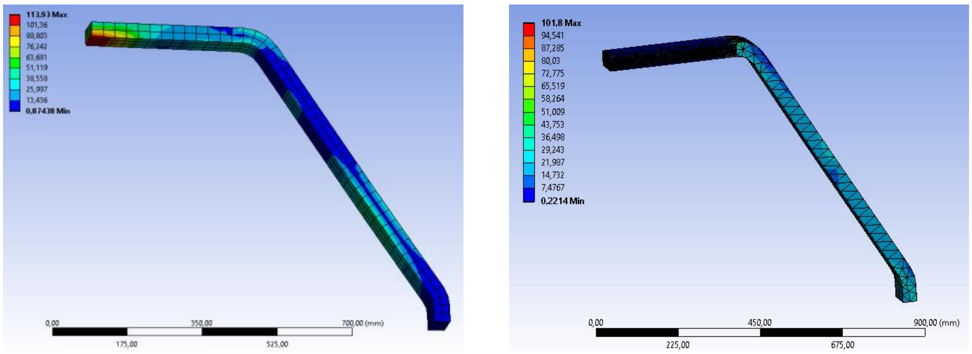
6. Comparative analysis of the models

After completing the finite element simulation, on the two landing gears, the maximum stress values were obtained for the peak intensity of the impact loading, for the considered landing case.

In figure 10, the maximum equivalent von Mises stresses are presented, for the two studied landing gears. It can be observed, that the maximum stress is 10 to 20% lower in the case of the hybrid landing gear in comparison with the landing gear made entirely of aluminium

Considering the results presented above, it can be said that the hybrid landing gear model has a better behaviour, for the given landing gear case in comparison with the one made entirely of aluminium.

Since in the analysis, the finite element model was simplified by considering a parallelepipedal geometry for the aircraft, which does not simulate with sufficient accuracy the stiffness of the aircraft, the obtained results cannot be considered sufficiently accurate. For an accurate finite element model, it is necessary to consider the entire geometry of the aircraft.



a) Stresses on the aluminium landing gear for the peak moment of the impact loading

b) Stresses on hybrid landing gear for the peak moment of the impact loading

Fig. 10. Peak von Mises stress values.

Due to the complexity of the finite element model, this cannot be achieved, because the complexity of this problem is well beyond the present computational power capabilities.

7. Conclusions

Following the obtained results from the finite element simulation of the two landing gear configurations, the following conclusions can be mentioned:

By comparing the maximum values of the stress charts for the two landing gears configurations, the use of composite honeycomb core materials leads to advantages in terms of maximum values and weight. The level of mechanical stress is also shown in Figure 10. The mass decrease of the structure is approximately 30%, approximation achieved by software estimation.

The numerical simulation was laborious but most suitable for obtaining data as close to reality as the modelling of the honeycomb structure can be done on other paths. The findings of this study must encourage builders to use such a structure.

Our analysis lacks the economic and technological factor that will lead to the adoption of such a solution in the future.

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