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MECHANICAL AND ACOUSTIC RESEARCH OF SOUND-ABSORBING COMPOSITE SANDWICH STRUCTURES FOR AIRCRAFT ENGINES

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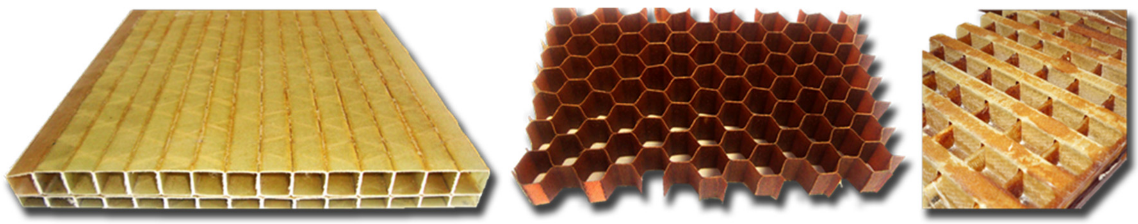
1. INTRODUCTION

Nowadays sandwich structures are widely used for the casing parts of aircraft engines. The initial primary function of such parts was the mechanical fastening of engine assemblies. Accordingly, they were required to ensure high mechanical properties - strength and rigidity. Then the International Civil Aviation Organization developed standards for noise emission of civil aircraft and now the second no less important function of these parts is to reduce the noise of the aircraft engines. It was found that the cells of the sandwich structure, when perforated by one of its shells, can interact with acoustic wave like a Helmholtz resonator. By varying the dimensions of the cells, the thickness of the shells and the diameter of the perforation holes, one can select the resonant frequency of the sandwich structure cells so that it corresponds to one of the main frequencies of the aircraft engine. Thus sandwich structures for casing parts of aircraft engines require effective sound absorption in a given frequency range and mechanical strength. The requirements of weight reduction for all aircraft structures lead to the use of composite materials for the manufacture of the sound-absorbing sandwich structures. The present work is devoted to solving of the actual problem of the modeling and development of effective aviation sound-absorbing sandwich structures, made of composite materials.

2. ACOUSTIC RESEARCH

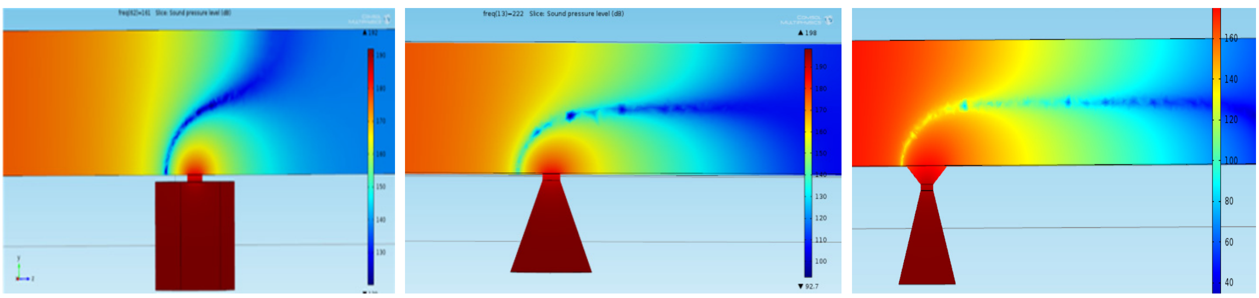
The modern aviation sound-absorbing composite sandwich structures consist of glass-fiber or carbon-fiber laminate skins and a core sandwiched between, which can have a tubular, cellular, honeycomb structure etc. (Fig.1).



(a) *(b)* *(c)*

Fig. 1: Types of core: tubular (a), honeycomb (b) and cellular (c).

The core cells interact with acoustic wave like a Helmholtz resonator and absorbing acoustic energy. For a given resonant frequency, the cell parameters are preliminarily calculated by the Helmholtz formula. After that the samples of the cells for testing on an interferometer are made. As a result of the tests, the sound absorption coefficient of the cells at different frequencies is determined. Then the numerical simulation of mono- and polychromatic acoustic wave interaction with one and group of the cells in the model channel was performed. As a result of numerical simulation, the effect of the shape of the cells on the coefficient of sound absorption was established. Distribution of the acoustic pressure inside the channel and on sidewall cell was found, loss factor of output acoustic pressure wave was calculated for variety of geometric forms of cell's chamber and neck (Fig. 2). Analysis of the acoustic pressure fields revealed that cell neck geometry strongly influences on cell resonant frequency and on outlet acoustic pressure loss factor. It was concluded that for effective sound absorption of sandwich structures, it is necessary to select not only the geometric parameters but also the shape of the core cells.



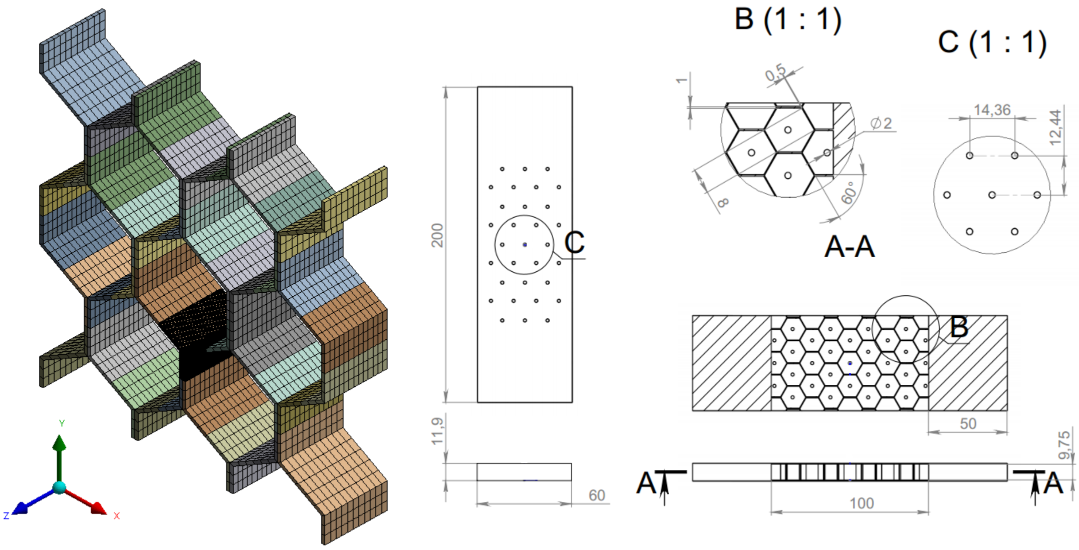
(a) *(b)* *(c)*

Fig. 2: Acoustic pressure fields inside the channel for various cell shapes: honeycomb (a), conical (b) and bi-conical (c).

3. MECHANICAL RESEARCH

The sound-absorbing composite sandwich structures serve also as load-bearing casing parts of aircraft engine. Therefore, ensuring their performance and structural integrity under various loading conditions is an important task which needs the solution of composite material mechanics problems. Depending on the purpose of the part and the nature of the loads, the solution of this task can be carried out in two directions.

The first way – the effective mechanical properties can be found for various types of core, which will simplify the further numerical modeling of complex structures. In present work, using analytical methods for isotropic materials, the verification of the developed algorithms for numerical analysis of the effective properties of honeycomb core made of both isotropic and orthotropic material, was performed (Fig.3).



(a) *(b)*

Fig. 3: Finite element model of honeycomb core (a) and scheme of sandwich panel (b).

The second way - the whole model, including the structure of core and laminated composite face sheets, can be used for simulation. Thus, the multilevel 3D models (Fig. 4) of panels with various types of core corresponding to full-scale samples used for mechanical tests were created for numerical prediction of their effective mechanical properties and analysis of non-uniform stress-strain fields distribution [1-2]. The numerical stress-strain analysis of panels under various loading condition was obtained with ANSYS Workbench software using the ACP module. Initial mechanical properties and strength characteristics of the materials used in numerical studies were obtained in in-house tests.

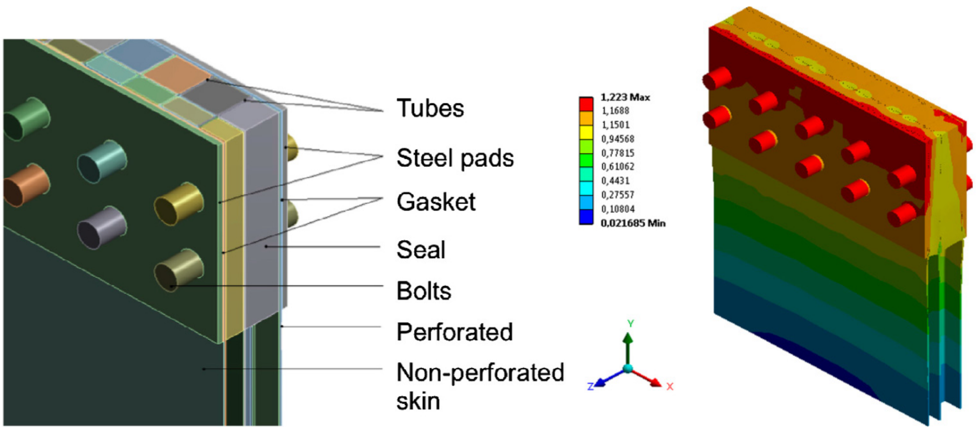


Fig. 4: 3D model of sandwich panel for FEM analysis.

The experimental verification of the developed numerical models was carried out with the help of specimens of panels made of ABS plastic and produced by 3D printing (Fig. 5). Static tensile tests were conducted on Zwick / Roell ProLine Z100 testing machine. The results of numerical simulation were compared to results of samples tension tests – good correlation was found.

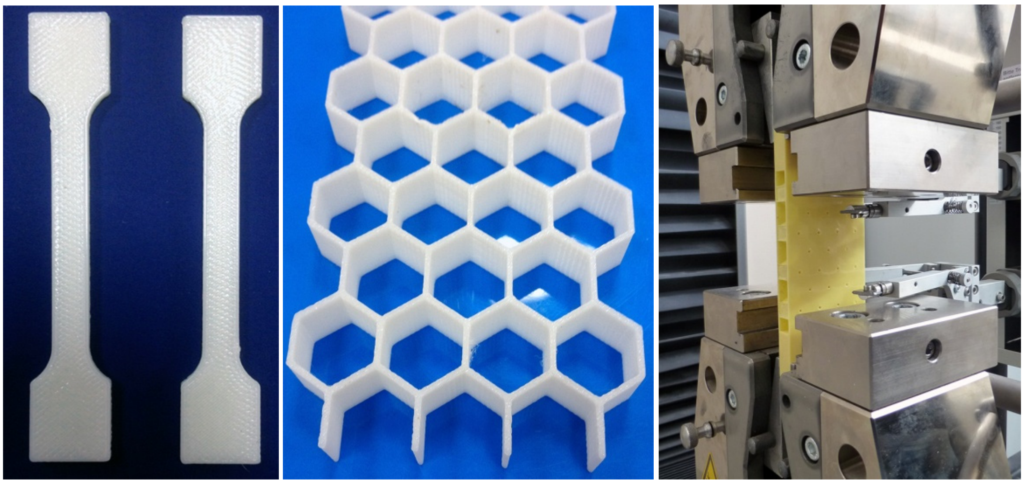


Fig. 5: Testing specimens made of ABS plastic.

4. CONCLUSIONS

Numerical models of sandwich structures from composite materials have been developed. The models allow solving problems of propagation of acoustic waves in sandwich structures and problems of mechanical deformation of sandwich structures. As a result of solving these problems, it is possible to predict absorption coefficients of acoustic waves and mechanical properties for different sandwich structures. It is supposed to use the developed models for the design of sound-absorbing composite casing parts of aircraft engines.

ACKNOWLEDGMENTS

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REFERENCES

[1] A.N. Anoshkin et al., "Repair of damage in aircraft composite sound-absorbing panels", *Compos. Struct.*, 2015, 120: 153–166

[2] A.N. Anoshkin et al.,"Experimental-theoretical research of mechanical properties of perforated composite sandwich panels", *Solid State Phenom.*, 2016, 243: 1–10.