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Application of short fiber reinforced composite materials multilevel model for design of ultra-light aerospace structures

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Abstract

A Multilevel approach of modeling the stiffness and strength of ultra-light aerospace structures from short reinforced composite materials is presented. The object of the research is the strength elements of aerospace structures and specifically, the lugs for the transfer of concentrated forces in the gateway of unit places. The material is anisotropic. The properties of this material depend on the organization of the casting process of the plates from which the lugs are cut. The first level of the model is the descriptive model of the casting process of the plate from PEEK material. The casting model of plates is based on the geometry of the gating system and the tool geometry which defines the characteristics of the high-viscosity heat exchange, reinforced during binding with the environment. The preprocessor for the first level of model production is Moldex Designer, with which the geometrical characteristics of the gating system of heat exchange are set. The finite-element mesh for calculation of the hydrodynamic task is constructed. Calculation of casting process of the gate is carried out in Moldex 3D system. The initial data are the finite-element model, the parameters defining the casting mode: temperature, pressure, material volume, and also the parameters of modes of hold pressure and cooling of detail. The orientation of the file of fibers, which is used for the description of the anisotropy of the products considered is the result of casting modeling of the plate. The second level of the model is the model of anisotropic material with the characteristics defined taking the orientation of reinforcing fibers into account, obtained from the results of the casting process in the DIGIMAT system. The possibility of detailing the material characteristics received on the basis of the processing of strength tests of material samples is considered. The third level of model is the finite-element model of the product considering anisotropy of material. The model is constructed in the ANSYS Workbench system. The strength characteristics of the anisotropic material are defined in the model by the DIGIMAT module connected to ANSYS through the material parameter setting DIGIMAT Material. The multilevel model allows calculation of the strain-stress state of products of irregular shape cast from composite materials reinforced by short high-strength fibers. The results of the multilevel model production are verified with field research of the considered products.

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Keywords: Short-fiber composite, multilevel model, aerospace structures, casting, static structural analysis

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1. Introduction

Composite materials reinforced with short fibers combine the unique properties of traditional polymer composite materials and the high technological capability of production by casting under pressure in forms. These materials can be used for production of parts of any difficult geometrical form while maintaining high mechanical characteristics at a low specific weight of product. Creation of control technology of melt flow and arrangement of fibers in such materials allows the predefined mechanical characteristics of the product in the required directions to be obtaine. The structural nodes made of such materials combine the advantages of metals not exposed to violation of structure and high weight performance. A composite material based on short carbon fibers (PEEK/CF) possesses the highest mechanical characteristics. Such material has a high modulus of elasticity and, at the same time, a high strength limit. The research is devoted to development of design methods of products from PEEK/CF and the technologies of their production. Orientation problems in FRT processing are difficult to solve without simplification, despite research [1-9] based on modeling polymer behavior at completing forms . The model of fiber orientation is important for the accurate forecast of characteristics. The Folgar-Tucker model [5] is used extensively to define the state change of fiber orientation. The predicted rate of change of fibers orientation with respect to time is higher than experimentally observed. To eliminate this difference Wang et al. [8] developed a new model, which is called the reduced strain closure (RSC) model. This model is an upgraded Folgar-Tucker model in which the scalar factor reduces own velocity of orientation tensor values in absence of changes in own velocity vectors. Phelps and Tucker [6, 9] proposed the use of a two-dimensional diffusion tensor on a surface of spherical coordinate system for the anisotropic rotary diffusion orientation equation. The ARD is an upgraded Hand's Tensor [10], which depends on velocity-strain tensor and orientation tensor. They are the union of the RSC Wang et al model. [8] and the ARD model for ARD-RSC model with six controlled parameters. Tseng et al. [11] developed a new model of fiber orientation which is called Improved Anisotropic Rotary Diffusion Model combined with Retarding Principal Rate Model (iARD-RPR). The iARD model describes the anisotropic properties of the fiber orientation, and the RPR model reduces the rate of change of orientation. This model has been used by Moldex3D VR-R11 from CoreTech System Co, Ltd.

2. Multilevel approach for short fiber reinforced composite materials

To forecast the mechanical characteristics of materials reinforced with short fibers there is the need for mathematical modeling of the casting process of non-Newtonian fluids with the subsequent experimental verification of the results obtained. The characteristics of products received by injection formation depend on all production stages. The directions of reinforcing fibers are set during the casting process. The area of blank part from which the part will be cut is defined in the process of mechanical operation. The load on the product depends on its ways of maintenance. Therefore the forecast of mechanical characteristics of such products demands a multilevel approach: sequential simulation of casting processes, mechanical operation and loading (Fig. 1). The objective of the work is the development of recommendations for the creation of multilevel models of fiber composite materials and their use in calculations of aerospace designs of the special strength criteria of composite materials reinforced by short high-strength fibers.

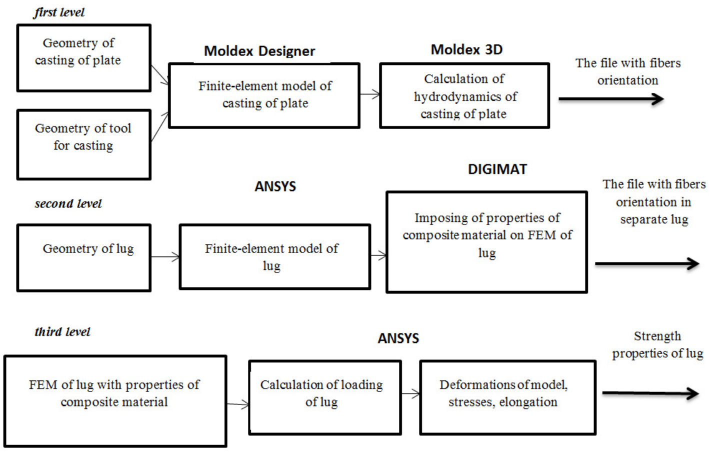

Fig. 1. Scheme of multilevel approach.