Forecasting the Residual Stresses in a Polymer Layer Manufactured Additively by the Technology of Centrifugal Material Application

Dmitry A. Parshin

Ishlinsky Institute for Problems in Mechanics of the Russian Academy of Sciences (IPMech RAS)
Prospekt Vernadskogo 101-1, 119526 Moscow, Russia
e-mail: parshin@ipmnet.ru, web page: http://ipmnet.ru

Bauman Moscow State Technical University
Ulitza 2-ya Baumanskaya 5/1, 105005 Moscow, Russia
e-mail: parshin_da@bmstu.ru, web page: http://bmstu.ru

ABSTRACT

Additive manufacturing processes accompanied with increase of solids in size by means of adding new material layers to their surface are characterized by the fact that the solids do not exist in their final configurations before the start of deforming, versus classical solid mechanics, as all additively manufactured solids keep being formed in course of the deformation. The mechanical analysis of additive processes has to take into account external loads actual in the simulated technological process, including those acting on the additional material, simultaneously with mechanical peculiarities of gradual attaching the material to the solid surface. Such account cannot be correctly carried out within the framework of classical solid mechanics, even if the traditional equations and boundary conditions are formulated for a time variable spatial domain. This is due to absence of any unstressed configuration for the entire additive-manufactured solid. Thus, the problems on mechanical modelling for additive-manufactured solids constitute a special class of problems in solid mechanics and possess a number of non-classical features. Approaches to statement and solution of such problems are being developed nowadays by Russian scientific school in mechanics of additive processes founded by Professor A.V. Manzhirov (see, e.g., works [1–3]).

In the present study the additive technological processes of layer-by-layer manufacturing polymer pieces on the inner surface of a rotating cylindrical substrate are investigated. Polymer materials exhibit rheological mechanical properties. Their behavior is described in the study in the framework of the linear hereditary theory of viscoelasticity of aging media. A non-classical mechanical model of the processes in question is proposed. The model is based on considerations of the current theory of additively formed deformable solids. The boundary-value problem for description of the deformation process of the being formed polymer layer under the simultaneous action of centrifugal forces is formulated. Its analytical solution is obtained. The evolvement of the stress state of the layer during and after its manufacturing is described. The found distributions of technological stresses in the produced layer depend on the realized manufacturing regime and essentially differ from the classical stress distributions in a similar rotating polymer layer that has not undergone straining factors during the process of manufacturing. The mentioned difference is explained by fundamental mechanical features of the additive process itself and causes the inevitable occurrence of residual stresses in the finished layer after stopping its rotation and, if it is relevant, after its detaching from the substrate. The distributions of these residual stresses are found and analyzed in the study.

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