Shape Defects of Cell-Filled Photopolymer DLP-Prototypes

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The manufacturing process of ceramic molds begins with the creation of the prototype. The layering synthesis technology (rapid prototyping, Digital Light Processing (DLP)) can significantly reduce the production time. In the layering build process, the object is built layer by layer from its computer CAD-model. This technology is implemented by stereolithography machine EnvisionTec Perfactory Xede with photopolymer composite Envisiontec SI500 (Mechanics and Technology Faculty, PNRPU).

The creation and solidification of the casting mold is followed by the process of high-temperature removal of modeling compound (burning). At this stage, the mold cracking problem occurs. To reduce the stress, a technology was proposed in which the monolithic (full-body) model prototype is replaced by a model consisting of a shell following the prototype shape and a cellular filler (Figure 1).

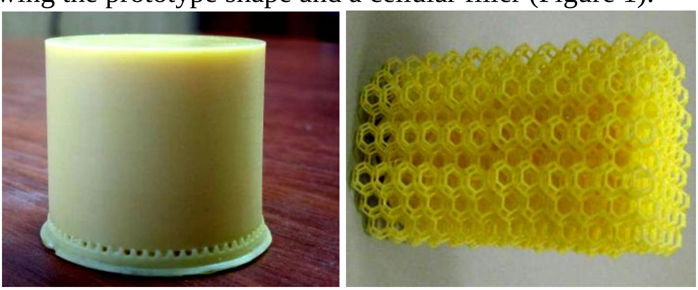

Figure 1: Cylindrical prototype (a) and cellular filler (b).

The aim of the research is to analyze the shape defects caused by material shrinkage during the layering build process and develop methods to address them. At this stage, a numerical algorithm for modeling the layered synthesis process is created using ANSYS Mechanical APDL package. To describe the behavior of the polymer, the modified hypoelastic model [1] is applied. The material constants for the photopolymer composite Envisiontec SI 500 were determined from thermomechanical experiments [2]. The material growing process was implemented using ANSYS "revival" of elements technology (Element Death and Birth).

A verification of the developed numerical technique was performed for a cylindrical specimen (Figure 1). In this case, the effective mechanical properties of the cellular filler set were found in numerical experiments. At the initial state, the shape of the future prototype geometric analog is ideal. Further, the geometry is divided into horizontal layers with thickness corresponding to the actual layer thickness (50–100 microns). The resulting framework is meshed by axisymmetric two-dimensional elements Solid183. Before the start of computations, all the elements are killed (EKILL command) and fixed in all degrees of freedom. The initial temperature is T_0=20°C. The build of the next layer consists of two steps. At the first step, all nodes attached to the layer are made free of constraints, and the elements are “reanimated” (EALIVE command). At the second step, the layer shrinkage is simulated by temperature reduction to T_1=20-1°C for 10–20 seconds. In this case, the dummy thermal expansion coefficient provides a linear shrinkage of 0.33%. After the growing process is finished, additional shrinkage related to final polymerization of the prototype in the light is given to the cylinder surface layers.

Experimental measurement of residual deformations was performed on a 3-coordinate measuring machine CONTURA G2 AKTIV. The instrument is designed to measure the size, position, and shape and to control caliber rings or caliber tubes. The measuring force varies between 50 and 1000 mN, and the measurement error is 5 microns.

The measurements were made on four diametrical intersecting paths on the upper planar face and on four vertical paths on the lateral surface. Figure 2 shows the measured relative displacements on the upper face of the cylinder (thin lines), their average values (thick black line) and the results of numerical calculations (thick red line).

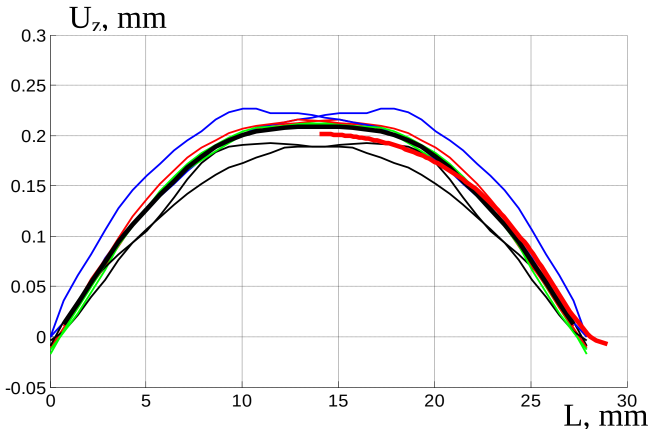

Figure 2: Relative residual axial displacements on the cylinder upper face

Similar research was carried out for the full-body photopolymer cylinder. It was shown that the residual shape deformation in a cellular specimen exceeds this parameter for the full-body prototype by about 50%. Further research will deal with the development of numerical technique for the inverse construction of the initial geometric model that takes into account residual distortion.

References

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[2] *O. Yu. Smetannikov and I .V. Samusev.* Experimental identification of constitutive equations parameters for photopolymer composite. Composite Mechanics and Design. Vol. 19. No. 1, pp. 105–116. 2013.