IMPROVEMENT OF THE DIMENSION ACCURACY OF THE PROCESS FOR RAPID PROTOTYPING OF CASTING PARTS BY RECONFIGURABLE FACET MOLDS

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Abstract: This study aims to present approach of the accuracy improvement of the reconfigurable facet molds process for rapid prototyping of casting parts using FEM simulation. Simulation will allow predicting thermal distortions and to rescale the 3D model put in account different scale factors in different directions in virtual phase. In the initial 3D geometry targeted to reach maximum value of accuracy of final molding components. The results obtained were implemented for small lots of nonferrous metal casting components manufacturing.

Keywords: RE-CONFIGURABLE FACET MOLD (RFM), RAPID PROTOTYPING, RAPID MOLDING, FEM, CAD

Introduction

The Rapid Prototyping (RP) and Rapid Tooling (RT) methods based on 3D computer models find an increasingly broader application in engineering. New ways are being sought to enable fast manufacturing of small batches of parts and the reconfigurable facet mold (RFM) methods emerge as some of the new trends in this field.

In these methods, the RT instrument is manufactured with the help of a RP mold against which bundles of needles are pressed [1, 5], thus providing a relatively accurate copy of the part surfaces for which the technological equipment is to be made – namely, a foundry mold (fig. 1).

Fig. 1 RT process with RFM

Since the parts are manufactured by means of casting methods as well as RP and RT techniques, the RFM technology introduces an extra error to the dimension accuracy, thus yielding to imprecise dimensions of the resultant parts. This article tries to examine the issues relating to improvement of the accuracy.

Experimental

One of the ways to correct accuracy is the use of a computer model employing a finite element method (FEM) – Fig. 2 [2, 3]. Firstly, a 3D model of the respective part is created based on a preliminary design (Step 1). This 3D model is used for FEM analyses which examine the changes in the accuracy of the part dimensions after completion of the full production cycle (Step 2). The FEM analysis gives correction coefficients which serve as input data for the 3D model (Step 3) to adjust the respective axial dimensions. Then, the 3D model is converted to an intermediary data transfer format (Step 4) and a prototype is produced using the RP selective laser sintering (SLS) method (Step 5). The RFM is made on the basis of this prototype (Step 6) and the prototype parts are manufactured by applying an appropriate casting method (Step 7 and 8). The parts cast using the relevant casting method are measured (Step 9) and the resultant dimensions are compared with the physical RP prototype (Step 10). If any differences are found, then appropriate correction coefficients are calculated to adjust the virtual model (Step 11). The cycle is repeated until a final part with correct dimensions is obtained (Steps 12–16).
The aim of the finite element method is to study the part behavior in the course of its production and ultimately to assess the accuracy of its form and dimensions. Using a package of finite elements, a model of the working area of the SLS RP machine is created where the part is built layer by layer out of powdered material. To simulate the building process, the technical properties of both the unsintered powder and the sintered (hardened) polyamide are input – density, specific heat capacity, heat conductivity, and the temperature-dependent elasticity module $E$. The layered building process is simulated by temperature alterations during the creation of each layer as a difference in the temperature required for surface melting and binding the powder particles [4].

Because of the symmetry of the test part, only one quarter of the casting part is taken into account in order to simplify the model and reduce the calculation time. The results of the thermal analysis are used as input data for structure analysis.

The changes in the part form are displayed on Fig. 3. It shows the logical behavior of the part elements (grills) folding their lateral sides as well as the relevant dimension changes.

The analysis allows us to assess numerically the deformation of the designed part caused by thermal loads. To verify the FEM model, the test part is produced on a RP machine.

Similarly, a FEM model can be defined to correspond to the process of obtaining a part using a RFM method. The factors which affect the production of parts by a RFM method are numerous and vary. Some of them are: temperature of the tool, temperature and composition of the melt, cooling time, heat conductivity of the mold, etc. Some of them can be controlled (maintained in certain limits), thus enabling us to influence the process and, hence, the dimension accuracy of the resultant parts.

After taking precise measurements of the physical model and making the necessary adjustments to the boundary conditions of the finite element model, we found that there is a difference in the results produced by the model and the actually measured dimensions and the changes in the form of the test part. This is due to the influence of various factors whose behavior is hard to forecast and put into the calculation model – for example, the constant change of the position of the laser spot and the resultant cooling process. The mathematical model outlines the tendency in the deformation of the test part which coincides with the actual changes in the form of the physical part. That is why this model can be regarded as truthful, particularly for forecasting deformations in more complex parts and identifying measures for eliminating such deformations.

To verify the operation of the computer model generated by using a FEM approach, a 3D model of the test part is created (Fig. 4). This part is one of the characteristics of the RFM method. The 3D model is adjusted with the coefficients obtained from the test part and the FEM part. Then the part is built following the SLS RP method (Fig. 5).
The RFM tool outfit is assembled on the basis of the test part and its internal and external relieves are impressed on the respective half-molds. Then the half-molds are fit together and the melted metal is poured into the cavity (Fig. 6). The test part is ready.

**Fig. 5 RP model of the test part**

**Fig. 6 Casting the melted metal and obtaining the finished part**

**Results and Discussion**

The proposed approach and its technological implementation allow us to improve the accuracy and usability of RFM-made parts without too many repetitions of the procedures to obtain correction coefficients. The following major conclusions can be drawn on the basis of the study described in this article:

- An approach that increases the RFM performance accuracy has been developed based on study of computer models with the help of FEM analyses.
- The results from the measurements of the part dimensions and their comparison with the initially input dimensions show that the finite element model is appropriate and it can be used to forecast changes in the dimensions of casting parts of various shapes in order to achieve greater accuracy.
- The complete technological process has been studied using FRM with an initially adjusted 3D simulated model, thus increasing the accuracy of work.
- The approach that we propose in this paper for information exchange and data transfer allows to adaptively correct the initial 3D model.

**References**


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