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ARCHIVES of FOUNDRY ENGINEERING

DOI: 10.2478/afe-2014-0055

Published quarterly as the organ of the Foundry Commission of the Polish Academy of Sciences

DE GRUYTER OPEN

ISSN (2299-2944)
Volume 14
Issue 3/2014

25 – 28

Shape Errors, Internal Porosity, Linear Dimensions Accuracy and Allowances for the Machining of Castings Made in the Replicast CS Process

R. Haratym[a], M. Sieczka[a], R. Biernacki[b]*, J. Kwapisz[c]

[a] University of Ecology and Management, Olszewska 12, 00-792 Warsaw

[b] Warsaw University of Technology, the Faculty of Production Engineering, ul. Narbutta 85, 02-524 Warsaw

[c] Instituto Superior Tecnico, MIT Portugal, Av. Rovisco Pais, 1, 1049-001 Lisboa, Portugal

*Corresponding author. E-mail address: r.biernacki@wip.pw.edu.pl

Received 30.04.2014; accepted in revised form 15.05.2014

Abstract

This research presents comprehensive assessment of the precision castings quality made in the Replicast CS process. The evaluation was made based on quality of the surface layer, shape errors and the accuracy of the linear dimensions. Studies were carried out on the modern equipment, among other things a Zeiss Calypso measuring machine and profilometer were used. Obtained results allowed comparing lost wax process models and Replicast CS process.

Key words: Replicast CS process, Shape errors, Dimensional accuracy

1. Introduction

Precision casting, which includes lost wax process, is an important area of foundry technologies. Number of castings produced in Poland is more than 600 Mg which value is estimated for over 16 million Euros. Increasingly important role in the countries that lead the world in investment casting plays Replicast CS process. This process allows the production of castings with greater dimensional accuracy and greater dimensions.

Mass production is carried out on average for about 20% of castings and is often associated with the determination of the minimum machining allowances, in the way that the small amount of surface layer and subsurface is removed. These layers have much better performance characteristics and determine on life expectancy of the product.

Determination of material excess for machining during small batch production highly depends on the agreement between the manufacturer and the customer. During mass production, the volume of material excess is primarily determined by the relationship between the precision of the casting and its nominal dimension. Amount of these allowances, is also often affected by inappropriate selection of the sprue and riser system. Selection of the sprue and risers can be based on publications [1,2]. Incorrectly specified amount of material for machining allowances, often cause an increase in the level of casting defects.

Determination of too big allowances shortens the life of the final product due to the removal of the surface layer. Surface layer of investment castings has the best properties. Removing it causes a significant increase in global energy intensity for the quantity of manufactured products and negatively affects the environment. The increase in energy intensity by 1 kWh will cost about 9.2 MJ [4].

Production of 1 kWh also results in the emission of approximately 700 grams of CO_2 and about 7 grams of SO_2 and about 4 grams of NO_x [5].

At the same time, on the basis of precision foundry observation in Poland, it can be seen that the main sprue (WG) is made from the mixture of paraffin and stearin with a low strength. The result is that the dimensions of the WG are overestimated. For example, a reduction in WG with ∅ 36 mm to ∅ 33 mm results in significant environmental effect and does not lead to shortages due to material supply.

2. Evaluation of castings shape errors

Due to the shape of casting made in Replicast CS process (Fig. 1) it accuracy was evaluated based on errors shown in Figure 2 and Figure 3.

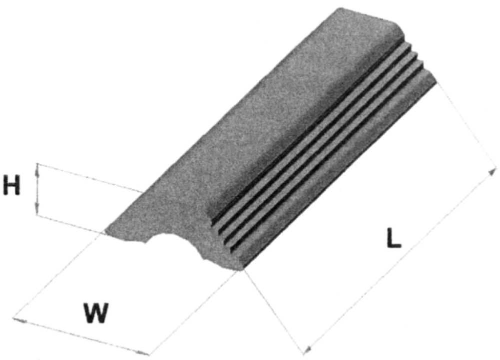

Fig. 1. The shape of pattern and casting

Casting defects, including flatness deviation (a large extent related to shrinkage), partially for the lost wax method is shown in reference [1]. Analyses were performed based on U.S. data and measurements of carbon steel castings, made in Polish foundries. There was no previous study for the Replicast CS process, which increasingly is used for the production of precision castings made of ceramic moulds.

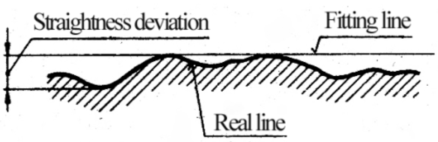

Fig. 2. Straightness deviation

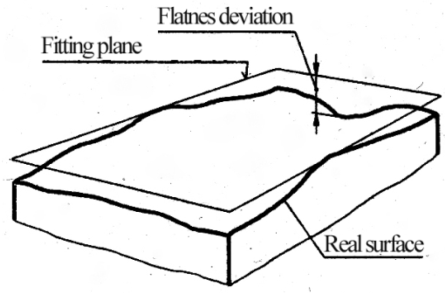

Fig. 3. Flatness deviation

Pattern and casting selected for research had solidification module equal to M_K = 0.24 cm (Fig. 1). Casting was performed using a pattern set shown in Figure 4.

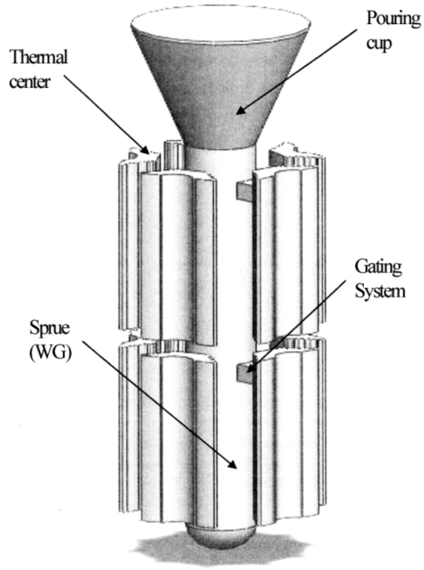

Fig. 4. Pattern set

Flatness error assessment was carried out for patterns and castings, based on measurements made on Zeiss Calypso measuring machine. Measurements were made at six points along the spine of the product on the length L (Fig. 1).

Based on the measurements for the entire group of patterns and castings the following data was obtained:

1) For patterns flatness deviation was
   $\Delta p = 0.0190 \div 0.0726$ mm,
2) For chromium molybdenum low-alloy cast steel, flatness deviation was $\Delta p = 0.1890 \div 0.3163$ mm.

The difference Δp between the pattern and casting ranges from 0.17 to 0.24 mm. It is linked with the Δp ceramic mould error and errors occurring in the phase of casting solidification.

Ceramic moulds were made from high quality materials. Ultra Remasol adhesive was used (the aqueous binder silicate) with the addition of polymers, slurry and aluminosilicates (Remasil).

3. Evaluation of material allowance for machining

The total value of machining allowances calculated analytically is the sum of half of the casting manufacturing tolerance. It takes into account the size of shape errors, surface quality, and the error associated with the determination of the base machining. Some researchers pay particular attention to surface defects and surface roughness of the castings. In the case of tested castings those were small values.

Precision castings manufactured in lost wax process, and also in the Replicast CS process should have virtually no surface defects. This should be a result of a smooth and a sterile ceramic mould surface (surface roughness of ceramic mould R_a defined basic attributes generally does not exceed 4 μm). For the casting shown in Figure 1, the surface roughness R_a were small and ranged from 3.52 μm to 4.90 μm. Sample profilogram is shown in Figure 5.

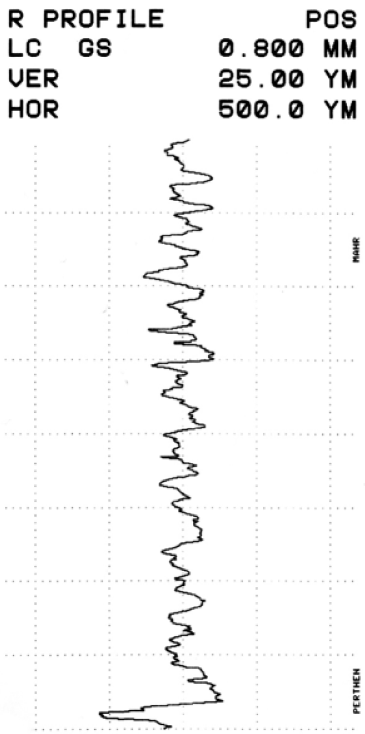

Fig. 5. Casting surface roughness profilogram from Fig. 1

Tolerances of castings resulting from the obtained results are described as $\Delta L_{6\sigma}$. For the Replicast CS process value of it was $\Delta L_{6\sigma} = 0.66 \div 0.9\ \% \cdot L_{nom}$. The average value $\Delta L_{6\sigma} \cong 0.8\% \cdot L_{nom}$ is close to $\Delta L_{6\sigma}$ of similar class castings made with usage of lost wax process.

Moreover for products (castings made using lost wax process), working to abrasion, surface which was not machined have bearing capacity for tp_{50} (50% R_{max}) equal to tp_{50} = 74.6%. This value is close to tp_{50} = 73% which was obtained after grinding [6].

Bearing capacity tp_{50} of studied castings produced in the Replicast CS process was in average equal to tp_{50} = 75.2%. Example of bearing capacity measurements made on profilometer S3P produced by Feinprüf Perthen GmbH company is shown in Figure 6.

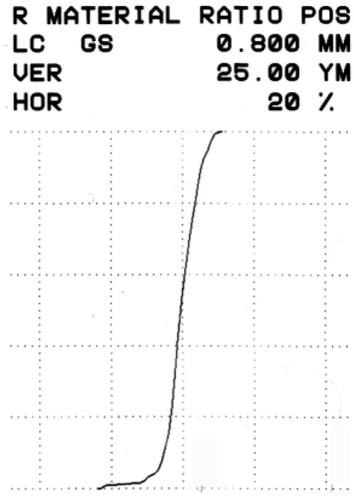

Fig. 6. Bearing capacity of casting from Fig. 1

Overall, it was assumed that during exploitation a large value of tp_{50} allows surface, which is exposed to friction or corrosion operation, work better.

4. Conclusions

Replicast CS process is similar to the lost wax process. If possible it is recommended to carefully select value of machining allowance in the way that it will not exceed the size of the surface layer and subsurface layer which is in total about 0.4 mm.

In most cases, for precision casting, it is recommended to avoid the use of machining allowance. This is due to the fact that the area, for which no machining has been used, has the special properties of the surface layer and the high value of tp_{50}. These parameters allow product to work twice as long during exploitation.

It is necessary to propose as often as possible production of precision castings with usage of Replicast CS process.

In addition usage of more durable mixtures as a material for sprue (in pattern sets) than the previously used on the basis of paraffin and stearin, can give a significant environmental effect as a reduction in the energy intensity.

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