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The quality of precision steel castings produced in the Replicast CS process

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Abstract

The quality in ceramic mould precision casting process include mostly surface quality of casts and their dimensional accuracy represented by six sigma deviation from the nominal dimensions ($\Delta L_{6\delta}$). This article present achieved results of examination of cast's surface finish. The dimensional analysis accuracy of expended polystyrene patterns and castings made from these patterns was executed.

Keywords: Quality of cast, Surface microgeometry, Replicast CS process , Dimensional accuracy

1. Introduction

Dimensional accuracy of precision castings produced in lost wax process or in Replicast CS process is the main issue. Around 30% of dimensional tolerance area is associated with accuracy and quality of patterns, and around 50% tolerance is associated with ceramic mould. Multilayer ceramic mould is made by fallowing of specific procedure with special attention to properties of ceramic slurry and type of loose ceramic material used to produce it. Accuracy of pattern mapping by ceramic slurry has major influence on micro geometry of ceramic mould surface, and on the cast. Accuracy of pattern mapping [2], and especially its surface is mostly a function of ceramic slurry properties such as surface tension, density, pole height of ceramic slurry during dipping of patterns in the mixture and ability to wetting patterns by the ceramic slurry.

During pouring liquid steel into the hot ceramic moulds different phenomena occur, which affects micro geometry of casts surface. The biggest influence has wetting of ceramic moulds by liquid steel, height of steel pole affecting ceramic moulds, and surface tension. Moreover, big role play wetting ability ceramic moulds by liquid steel. For example for aluminium alloy wetting angle θ is above 120 degrees [1] which show low wetting ability of ceramic mould base. Increase in surface tension of steel above 1200 mN/m which is significantly higher than for aluminium [1] cause wetting angle θ to cross 110 degrees and ceramic mould is not wetted. Surface of ceramic mould is homogenous as shown in fig. 1 [4], and covered with recess (craters). Size of those craters is not bigger then 0,15 mm as shown in fig. 2 [4].

According to equation (1), [3]:

$$\Delta(L - M)^2 = \delta_{fc}^2 + \delta_{uf}^2 \quad (1)$$

Where:
L - nominal dimension of cast,
M - nominal dimension of pattern,
δ_{fc} - strain of ceramic mould ($\sum\delta_{fi}$),
δ_{uf} - strain of ceramic mould during liquid metal shrinkage and solidification,
$\Delta L_{6\delta}$.- the six sigma deviation of cast

Squared subtraction $\Delta\ (L - M)^2$ give an approximation of ceramic mould strain, which have more than 50% influence on casts precision $\Delta L_{6\delta}$.

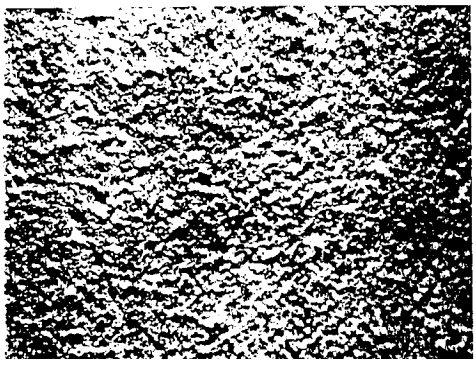

Fig. 1. Morphology of mould surface in 30 times magnification

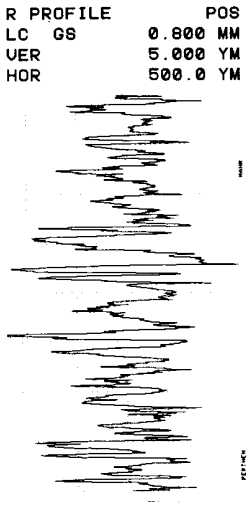

Fig. 2. Sample profilograph of ceramic mould surface

2. Examination of the surface of steel castings produced in the Replicast CS

2.1. Materials used in examination

Patterns were made from expanded polystyrene with 30 g/dm^3 density. Ceramic mould was made in further described steps: adhesive was a fumed silica with different latex – Ludox SK (layer 1) and Ludox PS 30 layers 3, 5, 7. The other layers from 2 to 8 included hydrolyzed ethyl silicate solution. Powder for ceramic slurry was based on SiO_2 and backfilling material was based on SiO_2 as well. Cast metal was a low-alloy steel, major elements of this steel was 0,4% C, around 1% chrome, 0,2% molybdenum.

2.2. Methodology of examination

Examination of cast's surface finish was made on digital profilometer Perthen Mahr S3P. To determine micro geometry of cast's surface R parameter was used (as a privileged) and R_{max} to determine value of curve of carrier participation tp_{50} (for 50% R_{max}). Determining curve of carrier participation tp_{50} will allow comparison of raw precision cast surface (which is not having any further surface finishing) with the element which surface was finished using some machining process.

2.3. Examination results

Gating system (fig. 3) used during production of precision casts is different than traditional used during casting in sand forms. Usually maximum pressure of liquid metal pole, shown by H_2 in fig. 3 is not exceeding 320 mm and is not smaller then H which usually is around 110 mm, in H_2 point is around 250 hPa and in H_1 100 hPa.

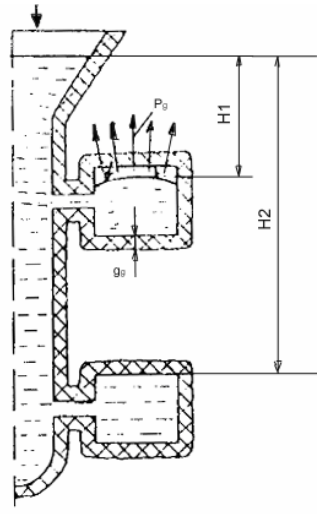

Fig. 3. Ceramic mould during pouring liquid metal in to it

In ceramic moulds plate cast's were made presented in fig. 4, the main diameter L was around 100 mm.

After those casts cooled down the surface finish was examined. Most focus was put on the examination of this wall of the cast which was closest to the sprue (W) and outside surfaces (Z) of cast on which sprue don't have thermal influence.

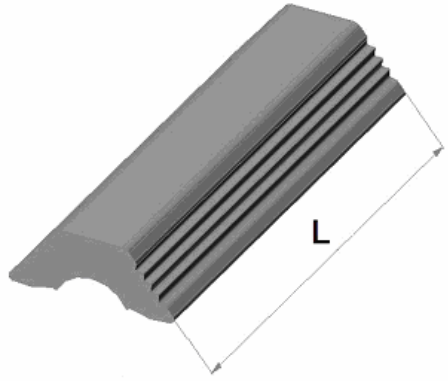

Fig. 4. Plate cast made from low-alloy steel

Module of cast solidification is equal on all of inside cast surface and approximately it equal to 0,7 cm, module for outside cast surface is approximately 0,4 cm.

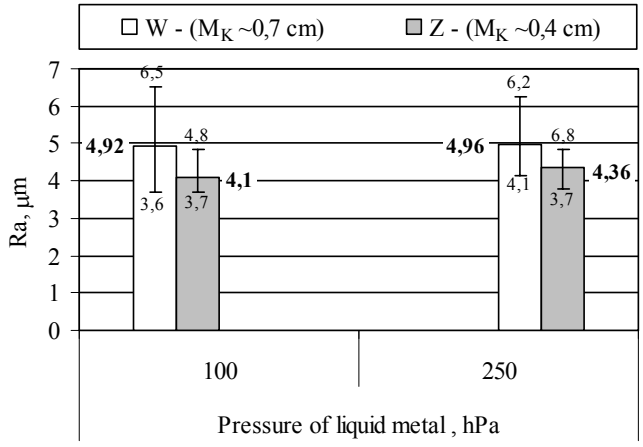

Fig. 5. Influence of pressure pole of liquid steel and the temperature of mold (estimated by comparison with M_K) on the value of Ra

According to fig. 5 the biggest influence on Ra has pressure of liquid metal in ceramic mould and value of solidification module M_K. Statistical dispersion of Ra value of inside surface of cast's is caused by change in permeability of ceramic mould during solidification of cast's. Several profilographs was made representing several distributed load. Sample profilograph from examination is shown on fig. 6 and fig. 7.

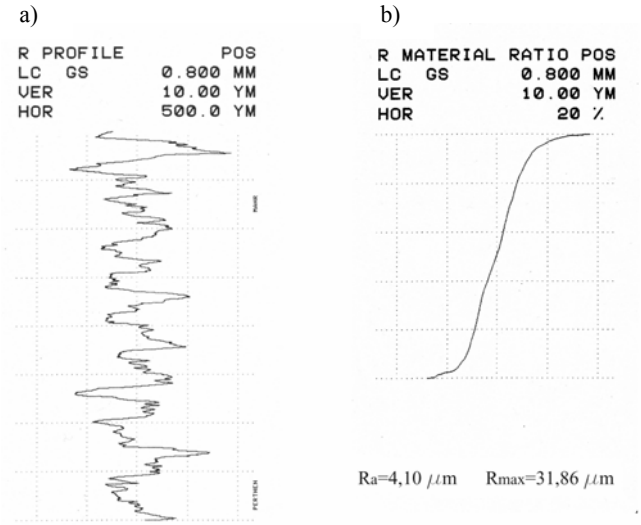

Fig. 6. Sample profilograph from examination of casts produced in Replicast CS process a) Ra, b) tp_{50}

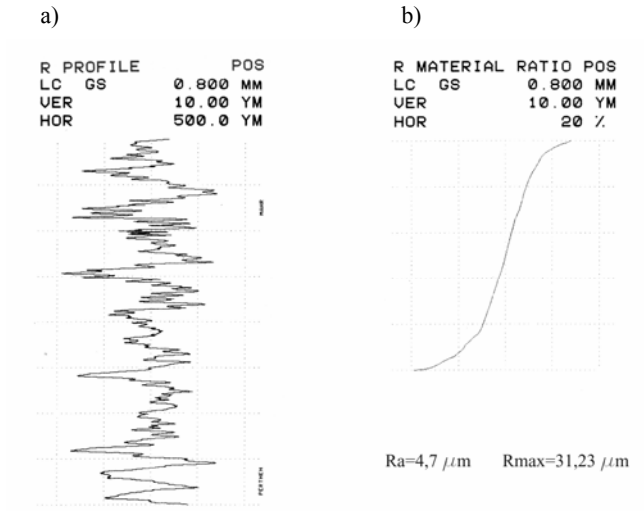

Fig. 7. Sample profilograph from examination of casts produced in Replicast CS process a) Ra, b) tp_{50}

Coefficient of roughness length of the carrier profile tp_{50} (for 50% R_{max}) of casting surface, suggests the possibility of passing load, causing for example wear of the surface layer of the device.

Obtained from the examination average value of tp_{50}=51% and maximum value of tp_{50}=63%. Based on the data [5] can be seen that the tp_{50} for surface steel products obtained after the finish machining have tp_{50}=60,2% (grinding), tp_{50}=63% or tp_{50}=41% (turning), so the values of tp_{50} is similar to those for the castings.

2.4. Evaluation of dimensional accuracy of precision steel castings obtained by a Replicast CS

Castings of the shape shown in fig. 4 were cast from low-alloy steel containing about 1% Cr and 0,2% Mo. Selected from a larger batch, for the dimensional analysis accuracy of 12 pieces of expended polystyrene patterns and 12 pieces of castings made from these patterns. Checked dimension L of the nominal value of around L_{nom}=99.50 mm.

For patterns six sigma deviation $\Delta M_{6\delta}$=0,29% M_{nom} and for castings $\Delta L_{6\delta}$=0,85% L_{nom}. Comparing the results with data [7] shows that the accuracy of the casting process Replicast CS coincides with the accuracy of casts made by lost wax process.

At the same time the value of $\Delta(L - M)^2$ is equal to 0.54%, which allows to get the value of strain of ceramic mould δ_{uf} with shrinkage errors arising during solidification of casting, which are about 0,6% L_{nom}.

Taken into account in this case, the strain of ceramic mould δ_{f1}=0,2% and δ_{f2}=0.19% [7]. Where δ_{f1} phase represent hardening and removing the patterns from the mould and δ_{f2} phase represent influence of temperature on the mould before pouring liquid metal in to the mould.

3. Conclusions

1. It has been proven that the process Replicast CS is equivalent to traditional lost wax process.
2. The parameters of surface microgeometry $Ra_{śr}$ was about 4,5 μm and the average of tp_{50}=51%.
3. Dimensional accuracy of castings was expressed by the parameter $\Delta L_{6\delta}$=0,85% L_{nom}.

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Jakość staliwnych odlewów precyzyjnych wytwarzanych w procesie Replicast CS

Streszczenie

Jakość w procesie odlewnictwa precyzyjnego w formy ceramiczne obejmuje przede wszystkim stan powierzchni odlewów i ich dokładność wymiarową rozumianą jako odchyłkę sześciosigmową wymiarów nominalnych ($\Delta L_{6\delta}$). W artykule zaprezentowano uzyskane wyniki badań stanu powierzchni odlewów. Wykonano analizę dokładności modeli z polistyrenu i odlewów wykonanych na tych modelach.