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Impact of analysis method on evaluation of ceramic mould surface microgeometry in the lost wax process

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Abstract

In this article two methods of ceramic mould surface microgeometry analysis were presented. First was a contact method, in which Profilometer S3P produced by Perthen Mahr was used. In second optical method optical profiler Veeco NT 9300 was used for surface microgeometry analysis. Evaluation of the results gathered with those methods was made. It was found that optical analysis method of surface microgeometry give better research possibilities (it's more optimal).

Keywords: Surface microgeometry, Ceramic mould, Lost wax process

1. Introduction

Currently, market need for precise casts made in investment casting process is growing. In the same time customers demand high quality casts, especially casts with high surface quality and with high dimensional accuracy.

One of the key aspects which allow introducing advanced casting technologies is interaction analysis of liquid metal and surface of ceramic mould.

Quality of casts surface (their roughness) is described by privileged Ra parameter, which is a function of extreme wetting angle θ of ceramic mould surface by liquid metal.

Interaction of ceramic mould surface microgeometry on wetting angle of ceramic mould surface by liquid metal.

Interaction of ceramic mould surface microgeometry on wetting angle θ is described by presented below equation:

$$\cos \theta_n = K\cos\theta_g$$

where:

θ_n - Wetting angle on rough surface,
θ_g - Wetting angle on smooth surface,
K - Coefficient of unfolded surface is defined as the ratio of true area of the rough surface to the ideally smooth surface.

In order to introduce new and improved manufacturing methods of ceramic moulds, better identification methods of surface microgeometry parameters need to be developed. Those need to include heat treatment process of ceramic moulds. Ceramic moulds in the aspect of microgeometry have a porous surface.

2. Methodology

Methodology of surface microgeometry analysis should allow optimal mapping. Profilometer S3P produced by Perthen Mahr was chosen to take those measurements. This profilometer can take measurements with head which don't have sliding contact, this allow getting real profile without any distortions.

Usage of digital filter allows removing unnecessary information such a waviness, or other distortions of signal.

In addition to the profilometer S3P produced by Perthen Mahr, another optical profiler Veeco NT 9300 was used for surface microgeometry analysis of the same ceramic mould patterns. Optical profiler Veeco analyzes surface topography in two dimension (2D) or three dimension (3D) roughness mapping.

This optical profiler system is installed in The Faculty of Materials Engineering of Warsaw University of Technology. During analysis of sample for this research purposes Vertical Scanning Interferometry (VSI) mode was used, in which maximum scanning height is 10 millimeters.

Sample surface topography of ceramic mould, made with usage of aluminosilicate as a base material and Ludox SK as an investment casting binder (first layer) is presented in Fig. 1. Analyzed area is a square in which sides have 0,8mm length (minimum measurement section in S3P profilometer is equal to 0,8mm as well).

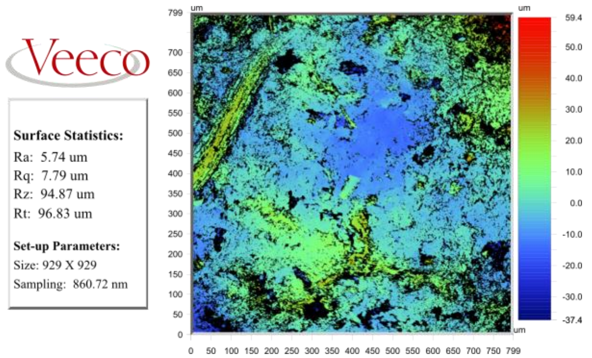


Fig. 1. Ceramic mould surface topography, sample M-X

Veeco optical profiler allow to present results in a graph which is usually made by profilometer SP3, Fig. 2 present such a graph.

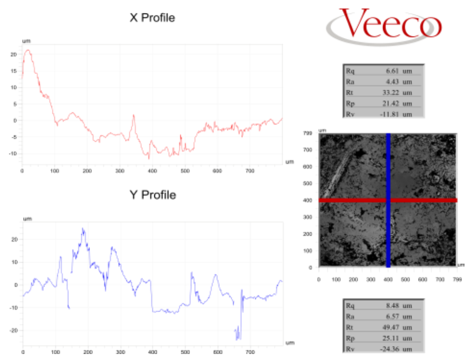


Fig. 2. Ceramic mould surface tophograpy, in the X and Y line area

Value of surface roughness parameter Ra, which was gathered by making measurements in X axis, is equal to 4,43µm, in Y axis Ra is equal to 6,57µm. Thickness of the measuring line in both axis is equal to 24µm (Thick line in Figure 1). Value of average surface roughness gathered from whole measured area (0,8mm x 0,8mm) is presented in Fig.1 and is equal to 5,74µm. Value of average surface roughness gathered only for X and Y axis is equal to 5,50 µm. Those results are very similar to each other. After analyzing Fig. 1 it's possible to determine that picture from this figure allow investigate larger areas of depression such as presented purple area. Approximately this depression size is around 250µm x 250µm and depth above 20µm and it is possible to compare it with radius r presented in Fig 3. [1]. Value of diameter r can be theoretically calculated from equation below:

$$r = \frac{2\sigma \cos\theta}{h\rho g}$$

in which:

h – is a average height of liquid metal column in ceramic mould,
ρ – metal density,
g – gravitational acceleration,
σ – surface tension,
θ – wetting angle of ceramic mould.

Value of depression from Fig. 1 will gave direct influence on the r value achieved in cast and calculated with equation 1.

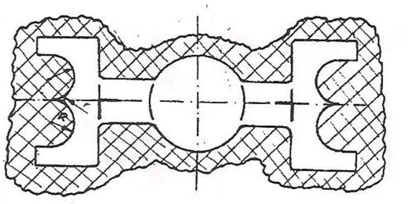


Fig. 3. Cross section of ceramic mould with marked rounding radius r

3. Results

For this research purposes 21 ceramic mould samples were made using ceramic aluminosilicate materials and SO_2, for the first layer water based silicate binder (environmental friendly binder) was used. Measurements were taken with profilometer S3P produced by Perthen Mahr, those measurements were made on all samples in three places. Length of measurements is a multiplication o minimum measurement distance which is 800µm. Results of those measurements are presented in Table 1 and 2.

Table 1.
The measurement results of samples of ceramic molds for profilometer S-3P produced by Pethen Mahr and optical profiler Vecco NT 9300

No.	Type of sample	Measured parameter – Ra [µm]					
		Profilometer S-3P			Profilometer Vecco NT 9300		
1	M	8,16	4,09	4,82	4,59	6,79	-
2	$M\text{-}X_3$	4,44	4,49	4,36	6,15	5,74	3,73
3	$M\text{-}X_1$	3,51	2,82	3,17	2,47	3,32	2,91
4	SiO_2-4	6,00	4,09	6,61	6,72	8,27	-
5	SiO_2-1	4,79	5,66	5,00	6,03	5,35	-
6	SiO_2-3	5,20	7,71	6,20	7,64	2,96	10,00

M - samples based on aluminosilicate.

Table 2.
The mean Ra measurements made on samples cut from different places of ceramic forms (see Fig. 4)

Place from which the samples were cut	Ra [µm] Samples M	Ra [µm] Samples SiO_2
G	4,70	5,70
D	4,43	3,62
B	3,51	2,27

G,D,B - Signs consistent with Fig.4

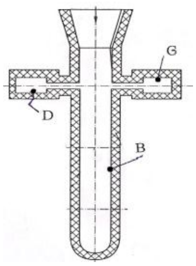


Fig. 4. Ceramic mould with marked G, D, B position

Measurements taken by optical profiler Veeco were made only on few chosen samples. Examples of results are presented in Figure 5 and 6. Chosen profilographs from profilometer S-3P are presented in Figure 7, 8 and 9.

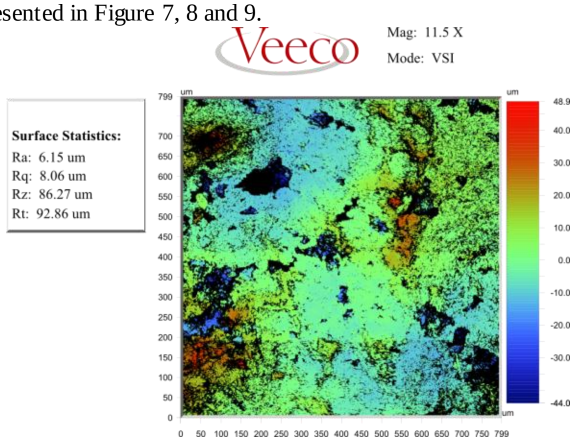


Fig. 5. Profilograph from optical profiler Veeco. Sample M-X3

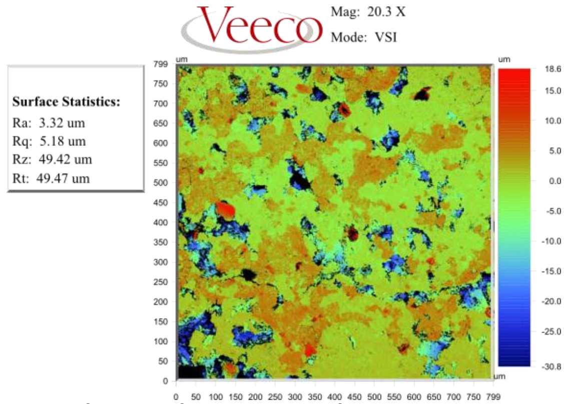
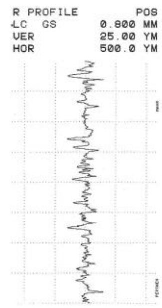
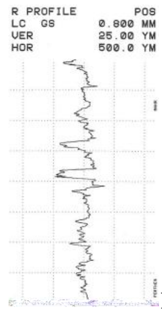


Fig. 6. Profilograph from optical profiler Veeco. Sample M-X1



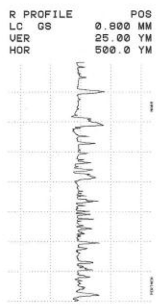
Ra=3,01µm

Fig. 7. Profilograph from profilometer S-3P. Sample M-X4



Ra = 4,44µm

Fig. 8. Profilograph from profilometer S-3P. Sample M-X3



Ra = 3,51µm

Fig. 9. Profilograph from profilometer S-3P. Sample M-X1

4. Analysis of the results

Based on the Table 1 it is possible to determine, that the results gathered with profilometer S3P and the optical profiler Veeco are similar. The main difference is that using optical profiler Vecco allows simply find places which will have influence on final surface microgeometry of the cast. It is due to possibility of three dimensional analyses of irregularities in the surface. On the other hand, by using profilometer S3P it is possible to make measurements on longer distances. In typical industrial research optical profiler is more optimal choice; because data gathered this way allow easier improvement of mould making technological process.

Analysis of the Table 2 confirmed previous research [2] about anisotropy of ceramic mould set. The main influence on it has the procedure of applying ceramic mould layers [3]. In the lost wax process it is necessary to deal with the relative motion to the pattern set first in the liquid ceramic slurry and then in moving mixture of air and fine ceramic material. In that situation typical fluidization can be observed. Moreover amount of liquid ceramic slurry which is in the end of the process which form single layer of ceramic mould in comparison to amount of fine ceramic material which is used to create one layer is different. The main differences can be observed in the upper and side surfaces. Additionally during heat treatment in temperatures above 900-1000C some of the binder is transforming in to crystal structure, which create empty spaces [4], [5]. That's the reason why value of Ra on the upper surface of ceramic mould is higher. This is presented in Table 2.

5. Conclusions

1. Measurements of ceramic mould surface microgeometry (object with high porosity) with usage of optical profiler Veeco give real image of surface topography.
2. Main disadvantage of optical profiler Veeco is a small area which is covered in singe measurement (in this case it was a 0,8mm x 0,8mm square).
3. When optical profiler Veeco is used for measurement of surface topography it allow improvement of first ceramic mould layer creation process in relationship with second layer.

References

[1] R. Haratym, J. Senkara, D. Sankowski, Oddziaływanie ciekłych stopów aluminium z powierzchnią form ceramicznych na spoiwach krzemianowych, Archiwum Technologii Maszyn i Automatyzacji, Poznań (2001).

[2] R. Haratym, Anizotropia własności form ceramicznych w aspekcie dokładności odlewów wytworzonych w procesie z przeciwciśnieniem, Archives of Foundry Engineering, vol. 5, No. 15, Warszawa (2008).

[3] R. Haratym, R. Biernacki, D. Myszka, Ekologiczne wytwarzanie dokładnych odlewów w formach ceramicznych, Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa (2008).

[4] H. Matysiak, R. Haratym, K. J. Kurzydłowski, Ocena właściwości wielowarstwowych form ceramicznych w aspekcie ochrony środowiska, Archives of Foundry Engineering, vol. 8; 2 (2008).

[5] R. Haratym, Wpływ zjawisk kapilarnych na kształtowanie warstwy wierzchniej formy ceramicznej w procesie wytapianych modeli, Sekcja teorii procesów odlewniczych Komitetu Metalurgii PAN, Poznań, październik 1998.

[6] Vecco promotional materials.