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Evaluation of 2D and 3D Surface Roughness of Die Castings from Alloy AlSi9Cu3

Ł. Pałyga, M. Stachowicz*, K. Granat
Department of Foundry Engineering, Polymers and Automation,
Wrocław University of Technology, Faculty of Mechanical Engineering,
Smoluchowskiego 25, 50-372 Wrocław, Poland
* Corresponding author. E-mail address: mateusz.stachowicz@pwr.edu.pl

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Abstract

This paper presents the possibility of evaluating the 3D surface roughness of a raw die castings made from alloy AlSi9Cu3, group EN AB-46000. Castings were produced on BUHLER H630-B die casting machine with various piston speed. The study was conducted on casting bracket for seatbacks office chair, whose surface do not require further machining to obtain adequate surface quality. In order to reduce the impact of possible surface mold roughness wear, the specimen has been taken from the places furthest away from the supply system. Evaluates of 3D surface roughness of specimens was performed on specialized software delivered with scanning electron microscope. After conducting a series of test on surface topography was evaluated roughness of raw castings produced with variable parameters of process control, such as piston speed during II Phase. It was found that the method used to measure 2D and 3D roughness parameters could be more practical in evaluating the quality of die castings, but it should be combined with the way their manufacturing and other destructive and non-destructive evaluation.

Keywords: Die casting, Roughness, Surface parameters, SEM

1. Introduction

High Pressure Die Casting belongs to manufacturing system, in which the permanent two-parted mold are used. The machinery, on which the castings are made, are called die casting machines. Due to the location of the chamber, the machines are divided into two groups: hot-chamber and cold-chamber. A typical casting material for hot-chamber machines are zinc alloys or magnesium, while for cold-chamber are aluminum alloys or magnesium alloys [1].

One of the many advantages of die casting aluminum alloy is getting large-net shaped castings and small roughness. The surface of the casting could achieve a roughness Ra of around 5 to 0.63 μm [2-3] marked according to standards PN-87/M-04251. Achieving low roughness of the casting depends not only on the state of the mold surface, but also on the quality of the liquid alloy, the selection of appropriate release-agents and the casting parameters.

The casting process is dependent on the working parameters of the piston, consisting of three phases. The first phase (I), there is a slow movement of the piston, which cause the gating system filled till the inlet gap. High-speed piston stroke in the next, second phase (II) fills the mold cavity. The last, third (III) phase, increases in pressure intensification metal [1]. Those three phases are present only in cold-chamber die casting machine with a horizontal piston. On the other technologies, the first two phases are only exist.

This paper attempts to link a surface roughness of selected raw castings to the casting parameters. The test specimens (left and right) were taken from flat and mechanically undamaged casting surface, furthest away from the feed casting system (see

Fig. 1) due to reducing the impact of possible mold wear caused by the operation of the stream of liquid metal. The mold was not covered by any coatings.

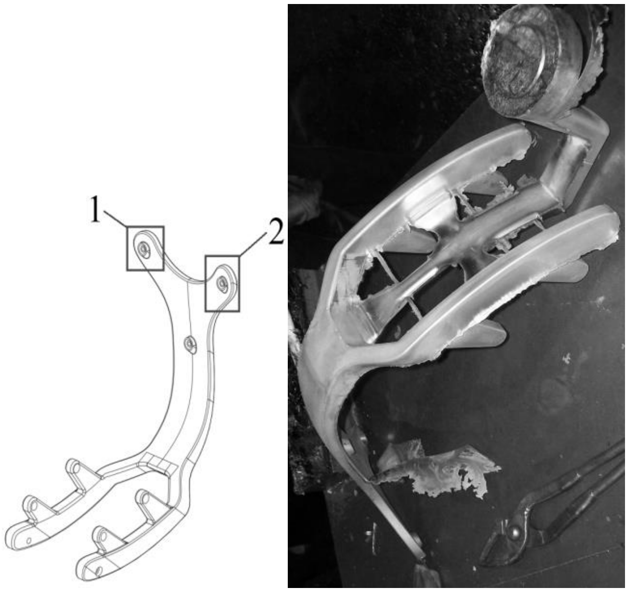

Fig. 1. Place of taking material for test specimens. (1) Left specimen, (2) right specimen and the view of raw casting with supply system, ejected from the machine

As shown in Figure 1 castings were made of an alloy from the group of EN AB-46000 (AlSi9Cu3) [4] on the modernized die casting machine BUHLER, type H630-B [5-7]. The temperature of the alloy during the pouring ranged from 720 to 740 °C. To evaluate the quality of an alloy, the measurement of the density index were performed. Before pouring the liquid alloy from burning furnace to holding furnace located at the machines, collected two specimens. The first specimen solidified under a vacuum of approximately 80 mbar, while the second specimen solidified in the open air. The results of a good quality alloy are in range of 2.5 to 2.8 g/cm^3. In this case the result of measuring the density index was 2.58 g/cm^3 [5]. After pouring the liquid metal from burning furnace to the transport ladle, the refining with nitrogen process is carried out for about 10 minutes [8].

From the series counting 36 castings, 4 casting were selected. The selected casting were made with various piston speed (II - second Phase valve). The set of third Phase (III) valve (multiplication) remain the same for all selected castings. The intensification pressure was 290 bar. Table 1 summarizes the II Phase valve parameters of selected raw casting.

Table 1.
The set parameter of II Phase valve [5]

Series	Set value of II Phase valve [%]	Measured piston speed [m/s]
A	10	0.3
B	20	0.75
C	60	1.2
D	80	2.3

2. Test stand

The casting surface photos were made with scanning electron microscope (SEM) by Hitachi model TM-3000. This microscope provides possibilities to observe the topography of specimens and is able to do its digital analysis [9].

Before the testing were conducted, the specimens have been cleaned and checked for mechanical damage and marked the places where roughness analysis were to be made.

All photographs were taken at the same magnification and the same electron beam source settings of 15 kV, providing the possibility of close observation and recording details of specimen surface.

As the test results of surface roughness were used following parameters:
SRa – arithmetic mean of absolute values,
SRq – root mean squared of values,
SRz – ten highest peaks and lowest valleys over the entire sampling length,
SRp – maximum peak height,
SRv – maximum valley depth,
SRlr – length profile coefficient,
SRSm – mean width of the roughness profile elements.

An analysis of the accuracy of the measured roughness was performed and compared with notched profile template. Due to the low conductivity of the profile template, it was necessary to do the sputter coating (Fig. 2a). The captured images were used to analyze the roughness of the 2D profile as shown in Fig. 2b. Table 2 presents the roughness results of a template after sputter coating and its nominal values given by producer.

Table 2.
The roughness results of a template after sputter coating

	Rp [µm]	Ra [µm]
Nominal	1.3	0.77
Measured	1.19	0.59

The test results of real roughness template differed slightly from the nominal values, which may be caused by additional carbon layer applied during template preparation for testing on microscope and necessary applied digital compensation profile convexity and concavity (Fig. 3) caused by the image capture. Applied digital roughness profile analysis method, according to prediction, had not affected on increasing the roughness parameters, and thus can be used to test the roughness raw castings.

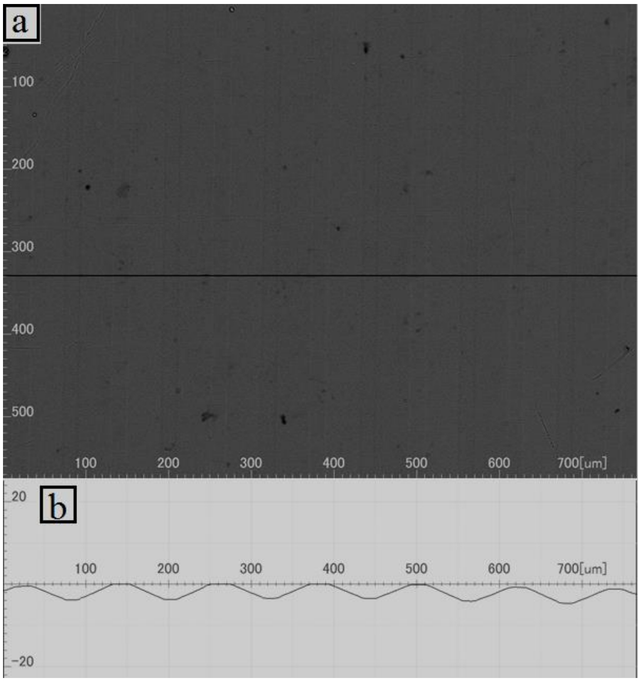

Fig. 2. View a) analyzed template surface, b) the transverse profile of the surface

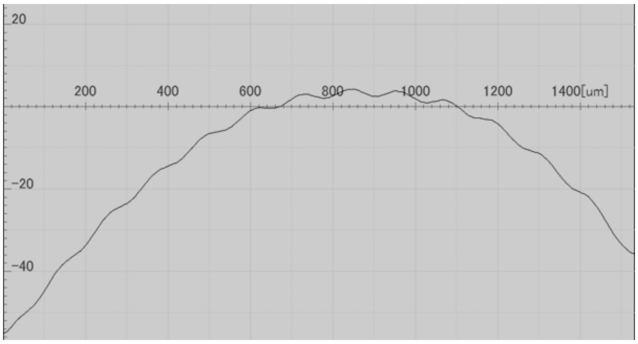

Fig. 3. The view of the transverse profile surface without digital compensation of convexity and concavity

3. Results

Figures 4 – 7 shows a surface view of the casting series: A, B, C, D after capturing the images on scanning electron microscope and its topography. Each image was taken with constant magnification 100x. In each figure, cases a) and b) show the actual surface view. Cases c) and d) show its topography. The measured area was a square with side length of about 2 mm.

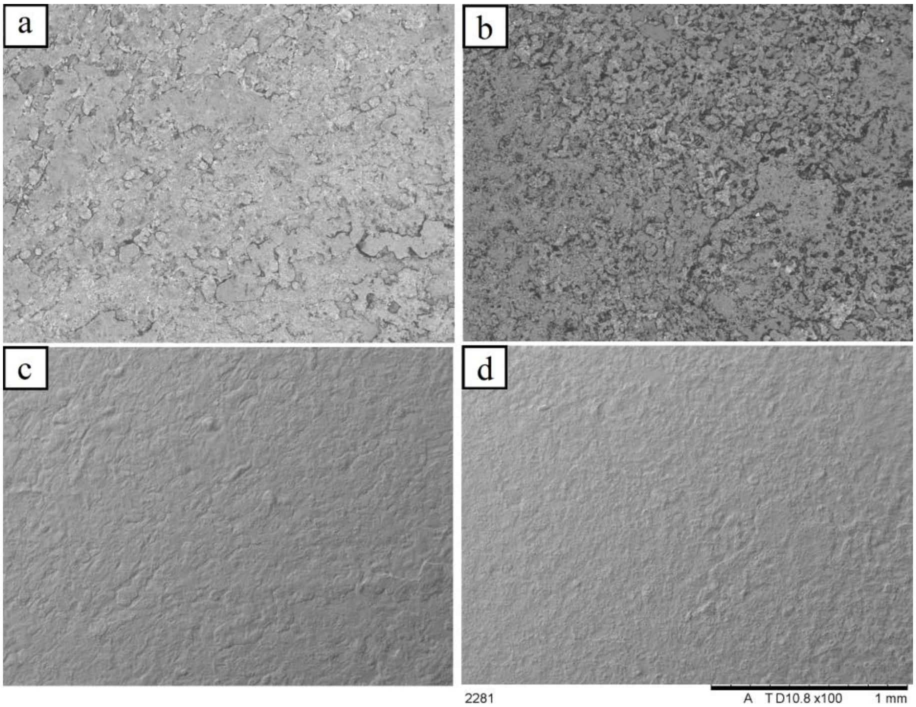

Fig. 4. The surface of the casting made with following parameters: piston speed 0.3 m/s, intensification pressure 290bar. (a) actual view of the left specimen, (b) actual view of the right specimen, (c) topography view of the left specimen, (d) topography view of the right specimen

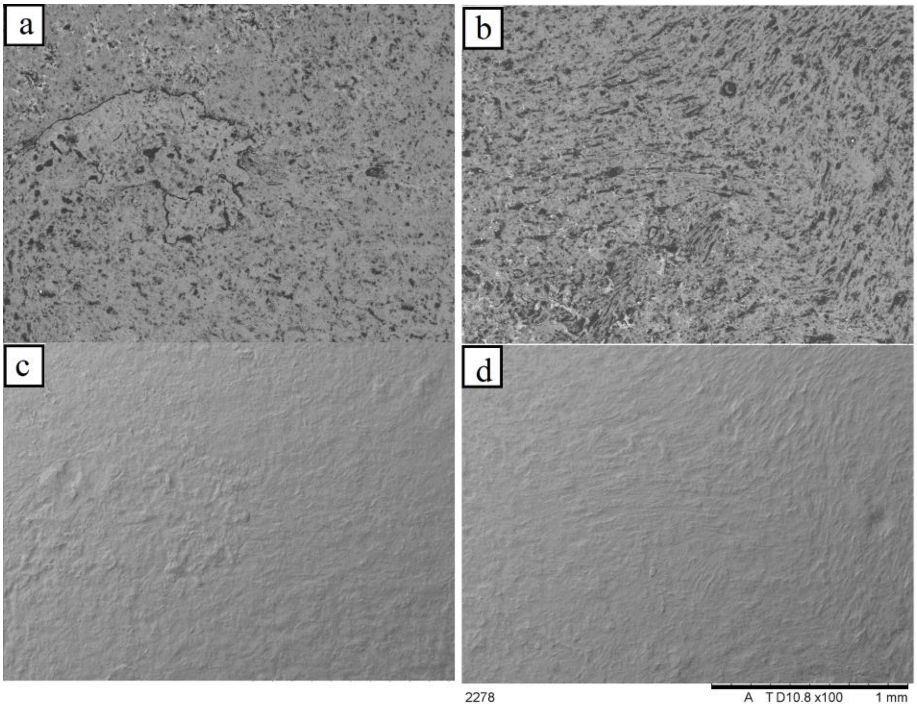

Fig. 5. The surface of the casting made with following parameters: piston speed 0.75 m/s, intensification pressure 290bar. (a) actual view of the left specimen, (b) actual view of the right specimen, (c) topography view of the left specimen, (d) topography view of the right specimen

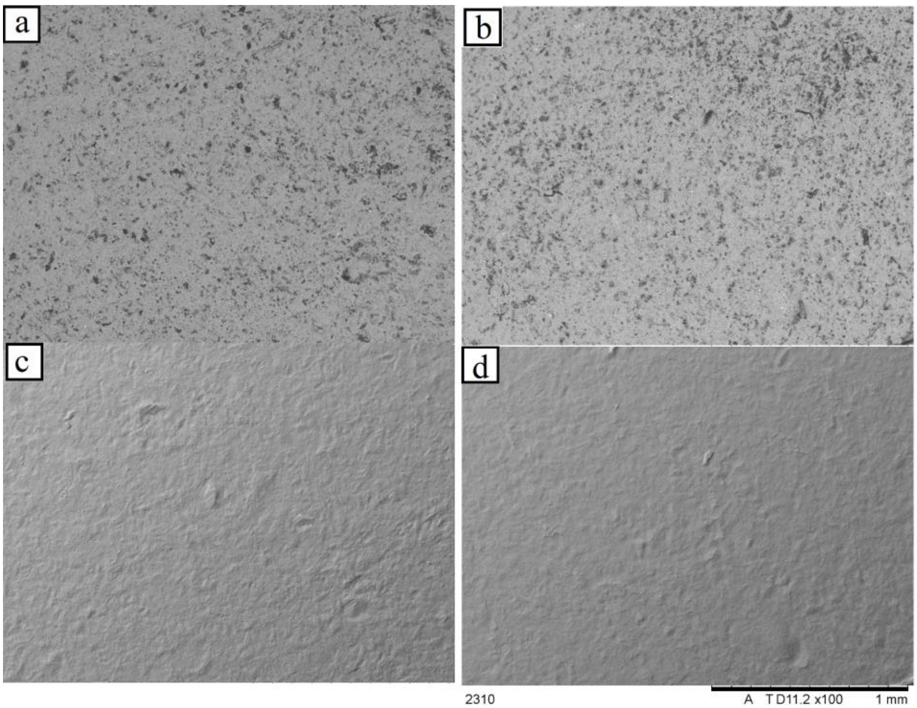

Fig. 6. The surface of the casting made with following parameters: piston speed 1.2 m/s, intensification pressure 290bar. (a) actual view of the left specimen, (b) actual view of the right specimen, (c) topography view of the left specimen, (d) topography view of the right specimen

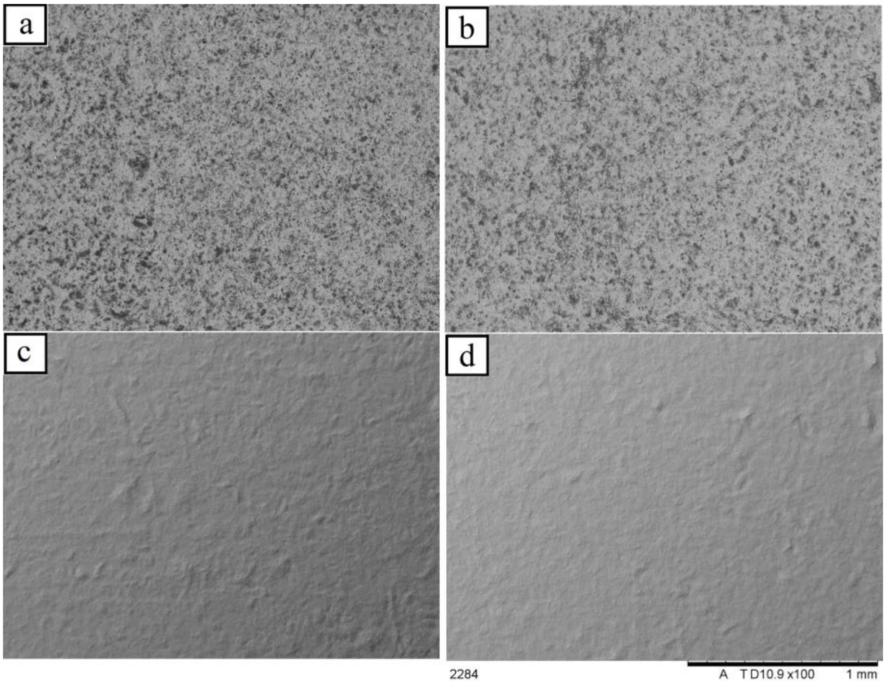

Fig. 7. The surface of the casting made with following parameters: piston speed 2.3 m/s, intensification pressure 290bar. (a) actual view of the left specimen, (b) actual view of the right specimen, (c) topography view of the left specimen, (d) topography view of the right specimen

From the observation carried out in the same casting surface areas, the influence on their appearance have different parameters of II Phase valve. It was noted, that derogations in series A (Fig. 4) and series B (Fig. 5) in the appearance of the topography comparing to the remaining series C and D. Topography observation revealed more details on the surface of the raw casting made with piston speeds of 0.3 and 0.75 m/s. The observations have shown the possibility of anomalies during the cast in series A and B. The next step was to make roughness analysis to confirm the surface topography observation. For this purpose, it was used with 3D roughness analysis with the aggregation of results function applied [9] measured at 20 elementary sections with 150x magnification (Fig. 8) with total length of 30618,83 µm. Table 3 shows the results of 3D roughness for all series of castings having regard to the average for the left and right specimen.

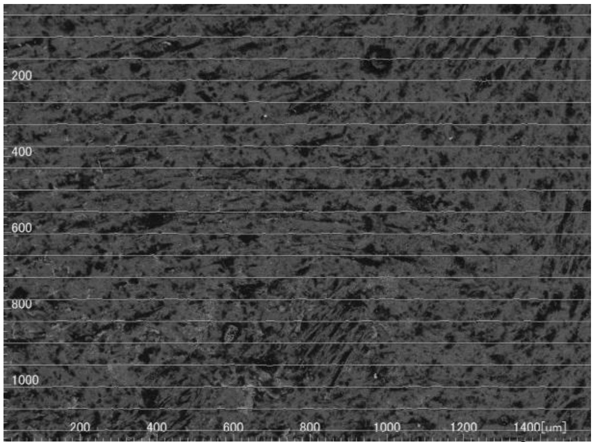

Fig. 8. View of a specimen area of 1 803 375,88 µm^2 with selected 20 measurement section for B series (right specimen).

Table 3.
Results of the surface roughness of specimens

Series – specimen	SRa [µm]	Avg.	SRq [µm]	Avg.	SRz [µm]	Avg.	SRv [µm]	Avg.	SRp [µm]	Avg.	SRIr [µm]	Avg.	SRSm [µm]	Avg.
A – left	0.75	0.855	1.06	1.2	11.18	11.87	5.37	5.775	5.81	6.095	101.14	101.48	53.35	**53.18**
A – right	0.96		1.34		12.56		6.18		6.38		101.82		**53.01**	
B – left	0.66	**0.635**	0.95	**0.91**	10.28	**9.645**	5.71	5.29	4.57	**4.355**	100.71	**100.69**	57.77	57.59
B – right	**0.61**		**0.87**		**9.01**		4.87		**4.14**		100.67		57.41	
C – left	0.78	0.735	1.13	1.06	12.98	13.52	5.2	4.92	7.78	8.6	100.89	100.78	60.04	64.53
C – right	0.69		0.99		14.06		4.64		9.42		100.67		69.02	
D – left	0.77	0.695	1.13	1.01	12.48	11.07	5.13	**4.685**	7.35	6.385	100.75	100.71	65.51	60.03
D – right	0.62		0.89		9.66		**4.24**		5.42		**100.66**		54.55	

The results of roughness of the right and left specimens, including arithmetic means listed in Table 3 confirm the observation in which the effect was noticed on the appearance of the casting surface [10] on different piston speed during II Phase. As a result in changing speed of cast, obtained surfaces differed in the amount of details, comparing series A (Fig. 4) and B (Fig. 5) to series C (Fig. 6) and D (Fig. 7). It was also noticed, that the specimens taken form the casting cast with recommended parameters (piston speed – 1.2 m/s) or twice the recommended (piston speed – 2.3 m/s) the results of the roughness analysis in series C and D are consistent with those expected. It has been observed that increasing the working parameters of the piston above 1.2 m/s results in a small improvement in all tested roughness parameters, however, it may have a negative effect on the durability on unprotected mold. Based on the results of 3D roughness, it was found that those specimens are characterized by the lowest valley depth (SRv – less than 5 µm for each of the series).

After analysis of the results contained in Table 3, it was found that the best parameters characterized by the casting form B series with the following casting parameters: piston speed 0.75 m/s, intensification pressure 290 bar. The specimen was characterized by the lowest arithmetic (SRa) and square root (SRq) mean of the values, minimum height of roughness profile (SRz), the smallest height of peaks (SRp) and the lowest ratio of the length of the profile (SRIr). The publications [5, 11] found, however, that the parameters used to cast from alloy AlSi9Cu3 in the casting series of B, there are many surface defects such as: surface blisters and micro shrinkage [12] in other than arms parts of the castings. A specimen taken from casting of series A, cast with low piston speed (0.3 m/s) has the lowest value of the mean width of the roughness profile elements (SRSm), but the biggest value of SRa. It was also noticed that die castings from that series had a lot of defects in other than arms parts.

4. Conclusions

Analyzing the test results, it was found that using a standard scanning electron microscope, used primarily to microscopic observation of the specimen surface, could also be use to surface roughness analysis, using image compensation functions on captured images.

Measured in this way roughness of a die casting are from alloy AlSi9Cu3 are similar in accordance with the shown in literature values [2, 3].

Due to the high sensitivity and accuracy of scanning electron microscope analyzing 2D and 3D profiles, it is very important to do the proper preparation of a specimen surface to be tested. Furthermore, it also needs to be limited, as far as possible, usage of sputter coating due to introduction additional. Error measurement resulting from the another applied surface layer may be difficult to compensate with a digital methods.

It was noticed, that the impact on surface roughness has piston speed during the II Phase. It is noted that at low speed of the piston (0.3 – 0.75 m/s – Series A and B) a great amount of details revealed from surface topography deviates significantly from the small amount of details from series C and D, cast at the speed of 1.2 m/s and above. Observations casting surface topography should therefore be combined with the analysis measured 3D roughness parameters and other destructive and non-destructive evaluations to avoid erroneous conclusions about the quality of the manufactured die castings.

Based on the results of the study, it was found, that a good surface quality is not always indicate the overall quality of the casting. Very important are the place where the specimen has been taken off of casting, the manufacturing of the casting and the preparation of the alloy. To thoroughly describe the impact on the quality of the die casting process, these issues should be considered comprehensively by combining many aspects of the die casting process.

References

[1] Perzyk, M. (2004). *Foundry*. Warszawa: Wydawnictwo WNT, ISBN 83-204-2931-5, (in Polish).

[2] Sobolewski, J. Z. (2012). *Manufacturing techniques. Chipless technologies*. Warszawa, Wydawnictwo: Studio Multigraf, ISBN 83-89703-71-8, (in Polish).

[3] Riddar, F., Hogmark, S. & Kassman Rudolphi, A. (2012). Comparison of anodised aluminum surfaces from four fabrication methods, *Journal of Materials Processing Technology*, vol. 212, 2272-2281.

[4] *http://stenametall.com/NR/rdonlyres/E242797C-89B1-48F9-A47C-546A3059064A/0/engENAB46000.pdf* [dostęp: 29.04.2015].

[5] Pałyga, Ł. (2014). *Analysis of the impact of automated control position for pouring the pressure on the conversion of the backrest support quality die-cast alloy EN AB 46000*, praca dyplomowa, Wrocław: Politechnika Wrocławska. (in Polish).

[6] Granat K., Pałyga Ł. & Stachowicz M. (2014). Diagnostics of control systems for pressure casting machines. Cluster - Casting - The Future*:* International scientific conference. Świlcza, 09-12.09.2014, Rzeszów 2014, 53-58, (in Polish).

[7] Granat, K., Pałyga, Ł. & Stachowicz, M. (2014). Research into the possibility of upgrading the control system pressure casting machines, *Archives of Foundry Engineering*. 2014, vol. 14, nr spec. 3, 55-60, (in Polish).

[8] Orłowicz, A.W., Mróz, M., Tupaj, M., Betlej, J.& Płoszaj, F. (2009). Influence of refining process on the porosity of high pressure die casting alloy Al-Si, *Archives of Foundry Engineering*, vol. 9, 35-40.

[9] *http://hitachi-hta.com/sites/default/files/literature/TM3000-TableTopSEM-BrochureHTD-E188Q.pdf* [dostęp: 29.04.2015].

[10] Sękowski, K., Piaskowski, J. & Wojtowicz, Z. (1972). *Atlas alloys standardized structures*. Wydawnictwo Naukowo-Techniczne. (in Polish).

[11] Granat, K., Pałyga, Ł. & Stachowicz, M. (2015). Effect of Selected Parameters of Pressure Die Casting on Quality of AlSi9Cu3 Castings, *Archives of Foundry Engineering*, vol. 15, 85-90.

[12] Kozakowski, S. (2001). *Research castings. Casting technologies, typical for them the pros and methods of their disclosure.* Warszawa: Wydawnictwo Biuro Gamma, ISBN 83-87848-2 (in Polish).