COMBINATION OF SURFACE AND VOLUME ANALYSIS METHODS IN THE STUDY OF THE QUALITY OF THIN-WALLED CASTINGS FROM ZP0410 ALLOY

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https://doi.org/10.37904/metal.2022.4513

Abstract

The technology of high-pressure die casting thin-walled castings requires increased demands on the stability of technological processes and pressure casting parameters. The wall thickness of the studied zinc alloy castings (ZP0410) ranges from 0.4 to 1.2 mm. In general, it is necessary to use higher mould operating temperatures and a higher casting speed when filling the mould cavity when casting thin-walled castings. There is an increased load on the mould (tool) and the die casting machine during this casting process and the use of more demanding parameters. It results in a shortening of mould service life. There is currently no own returnable material (alloy ZP0410) used in the given production conditions in the production of thin-walled castings. Only the primary alloy ZL0410 is used now. It must be emphasized that the ability to implement the recycling of these returnable materials is becoming increasingly important. However, it is necessary to ensure that the quality of production is not reduced. The research was carried out aimed at determining the current state. Methods of roughness analysis, computed tomography, and metallography of casting defects from casting machine failures even after plating are used in the study of existing production technology in addition to standard long-term monitoring of melt quality. The findings of these research activities were briefly summarized in the paper. The experimental development of the technology of using our own returnable material in this quality-intensive production is in progress now.

Keywords: Zinc alloys, melting, casting, recycling, returnable material

1. INTRODUCTION

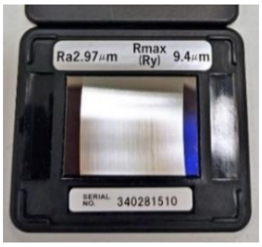
Zinc is the fourth most often utilized metal in the world. Zinc and its alloys are used predominantly in the chemical and automobile industry. Zinc-based alloys offer many characteristics which make them especially attractive to productions which use pressure casting and, in general, to foundry technologies. They are characterized by low melting temperature, which results in low energy consumption and high fluidity. The properties mentioned are advantageous at filling of complicated mould cavities and of very thin profiles [1]. Enumeration of the most often used foundry alloys is included in the standard for zinc and zinc alloys - castings (CSN EN 12844) [2]. Quality of the primary raw material ZL0410, which is used as a batch material for the relevant castings production, is defined in the standard CSN EN 1774 [3]. According to the study [4], computed tomography – CT - represents a revolution in the area of non-destructive testing and evaluation. This type of testing provides plans how to deal with defects, which fulfil specific requirements on visualization. Cracks caused by liquid metal could be analysed in the past in case of zinc alloys either by metallography or, as the case may be, a main fracture area was prepared and it was examined by an electron microscope. When using the original examination methods, some defects remained undetected. The three-dimensional computed tomography manages to display also all cracks, including their branching and forking. This technology allows analysis of the general picture of the cracks network, and, subsequently, it is possible to present the analysis using a 3D CAD model with already displayed defects [4]. From the viewpoint of the surface roughness measuring, a study [5] has been elaborated; it deals with casting temperature optimization on the thickness of a mould wall and on the thickness of a casting wall. Regarding the surface roughness continuity on a casting, this measuring is not too conclusive. Nevertheless, based on this output, the Z-Cast process in the traditional foundry practice has been improved [5]. It can be noted that the issue of zinc alloys foundry practice is published rather sporadically. On the other hand, many works deal with, for example, zinc utilization for plating, e.g. [6-8]. The relevant studies are focused on the percentage of certain elements, for example aluminium, nickel and lead. The reports allow a deeper study of a zinc alloy character [6-8]. The relevant research was rather focused on basic evaluation and the applied methods potential will be extended gradually. The basic evaluation by metallography was realized, in particular, because this method can be compared very well to the computed tomography (CT). The research [7] presented the influence of bismuth and tin, which were added into a Zn-AlNi bath, on microstructure and corrosion resistance of hot dipped galvanized plating. The study output provided an ascertainment that compared to the Zn-AlNi plating, the Zn-AlNiBiSn plating features lower corrosion resistance. [7]. Within the study [8], Al, Ni and Bi were added to the zinc bath and their influence on the plating microstructure and corrosion resistance was being observed. By adding the Bi admixture to the bath, it is possible to eliminate the use of Pb, which is harmful to the environment. The disadvantage of the Bi admixture use is a lower corrosion resistance of the plating [8].

The submitted paper is a part of a long-term and, considering the shortage of published outputs in the last decades, also unique systematic research of the issue of the zinc alloy ZP0410 castings production technology. Besides the insufficiently mapped matters of the own production and the influence of setting the parameters of the melt preparation, attention is also focused on implementation of the own returnable material utilization. This paper deals with a partial section of the scientific-research activities, namely with the study of surface and sub-surface quality of high-pressure die castings from the ZP0410 alloy.

2. EXPERIMENTAL PROCEDURE

Three methods were applied within the zinc components monitoring: measuring of the surface's roughness (primarily evaluated by *Ra*), volume scanning using computed tomography (CT) and light microscopy.

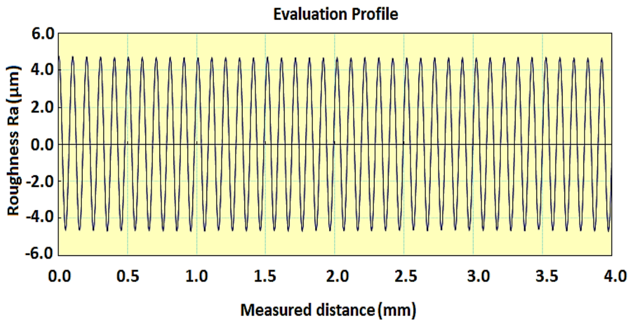
From the surface roughness measuring viewpoint are detected the surface geometric deviations from the ideal shape. Prior to the surface roughness measuring proper it is necessary to calibrate the instrument by a calibration plate (**Figure 1a**) and set the measuring conditions (**Figure 1b**). Subsequently, are obtained the measuring course graph (**Figure 1c**) and the calibration result, which must be within the tolerance of *Ra* = 2.97 ± 0.01 μm.



a) Standard

Standard	ISO 1997
Profile	R
λs	2.5 μm
N	5
Cut-Off	0.08mm
Filter	GAUSS
Work name	Sample
Measuring	SurfTest
Comment	Ver 2.00

b) Measurement chart



c) Measuring graph

Figure 1 Calibration process

The computed tomography (CT) is applied because it allows volumetric scanning of a part geometry and, subsequently, the data transferability to the STL digital file formats. Among other, the format can be used for additive production – 3D printing. In case of the submitted paper the method is applied for non-destructive testing, which detects, for example, cracks, porosity, internal deviations, hidden edges and misruns.

CT uses a rotating source of roentgen radiation which passes through the sample being analysed and which is captured by a detection system. The detectors record the roentgen radiation intensity decrease after it passed through the sample. The resulting measuring, even several hundreds measured from various angles, is subsequently processed by a computational software that allows creation of individual planar cross-sections of the sample. Using geometric digital processing of the cross sections, it is possible to create a 3D representation of the analysed sample, including recording of potential cavities in its volume. The computed tomography allows detection of cavities larger than 0.01 mm^3 in zinc alloys, determine their number and size and specify the porosity.

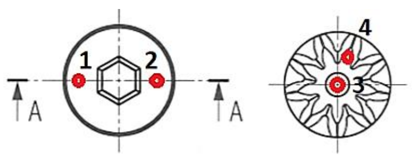
The third applied method is light metallography. The aim of this method is to visualize the material structure as much as possible and using a light microscope, examine the defects subsequently. This production mapping is essential for detecting undesirable surface and internal defects.

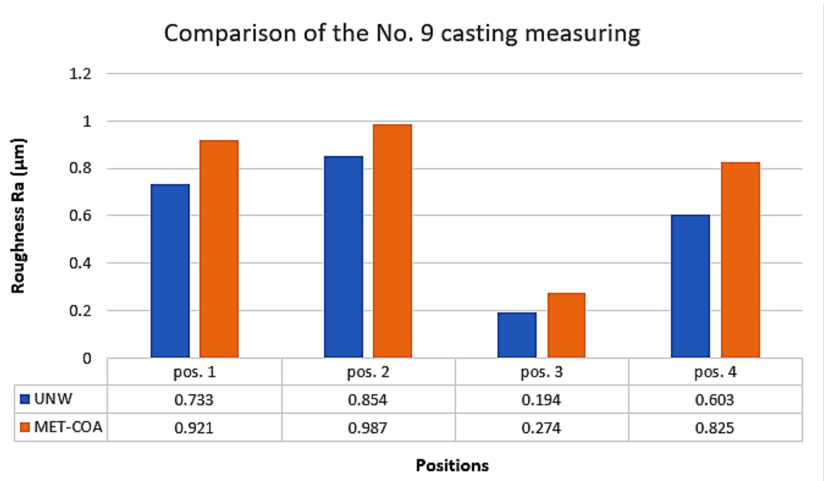
Within realization of the measuring method by light metallography are ascertained the following viewpoints: connections between material structure and its properties, material properties at production and subsequent processing, causes of the material defects.

First of all, the sample that is to be examined by light metallography was cut in selected areas and subsequently encased for better handling. After encasing, the samples were ground and polished on a metallographic grinder. Subsequently, an analysis on an OLYMPUS SZ61 stereomicroscope was performed on individual samples, which was focused on macro snaps obtaining. The following analysis on an inverted metallographic microscope OLYMPUS GX51 was focused on selected details analysis.

3. RESULTS AND DISCUSSION

With regard to the limited possibilities of this paper scope, the results proper are focused on one type of a casting, which is called „Kegelrad klein für Bajonettantrieb“ – casting No. 9 hereinafter, according to identification used within the research. Results of all the applied methods are described on the relevant casting. Before measuring the surface roughness of casting No. 9, it was necessary to specify four measuring points which are shown on **Figure 2a**.





a) Measuring points **b)** Comparison of the No. 9 casting measuring

Figure 2 Roughness measurement (Ra) of casting No. 9

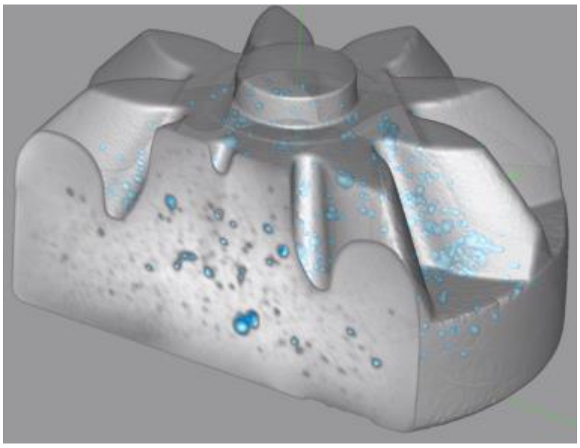
A graph was created from the measured Ra values; it is shown of **Figure 2b** with comparison of an unworked and metal-plated casting No. 9. Average values and standard deviations were determined using the relevant values which are specified in **Table 1**.

Table 1 Resulting measuring values

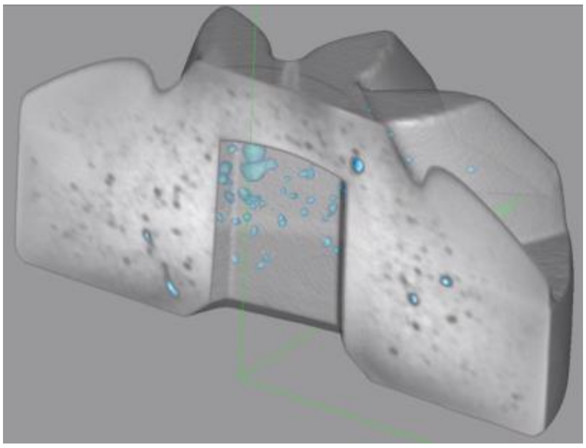
Casting type	Average value (*Ra*)	Standard deviation (*Ra*)	Units
Unworked	0.596	± 0.287	μm
Metal-coated	0.752	± 0.325	μm

Looking at the results on **Figure 2** it is evident that the highest roughness values *(Ra*) on the unworked and metal-plated casting were measured on position 2 (0.854 μm and 0.987 μm, respectively). The lowest Ra values were identified on position 3 (0.194 μm and 0.274 μm, respectively). **Table 1** shows that the average Ra value on the unworked and on the metal-plated casting is 0.596 μm, resp. 0.752 μm. **Table 1** also shows the unworked and the metal-plated casting standard deviation *Ra* is ± 0.287 μm and ± 0.325 μm, respectively. When looking at the values which were measured on the unworked casting, we can say that the metal-plated parts have higher surface roughness values (*Ra*). Nevertheless, within the complex study of various castings types it is quite the reverse, higher roughness (*Ra*) was achieved generally on unworked castings. Further study will confirm or invalidate whether this finding has any connection with the casting type, e.g., with thickness of the castings wall or with other properties of their geometry.

The next research stage was focused on computed tomography (CT). In total, 381 cavities were discovered in casting No. 9, which was scanned by CT; their total volume was 21.0393 mm^3, and with regard to the casting volume of 4895.0155 mm^3 it corresponds to porosity of 0.4298 %. **Figure 3a**; resp. **b** shows cross-sections of a three-dimensional casting representation, obtained by computed tomography. Cavities occurrence in the casting volume and their distribution is evident.



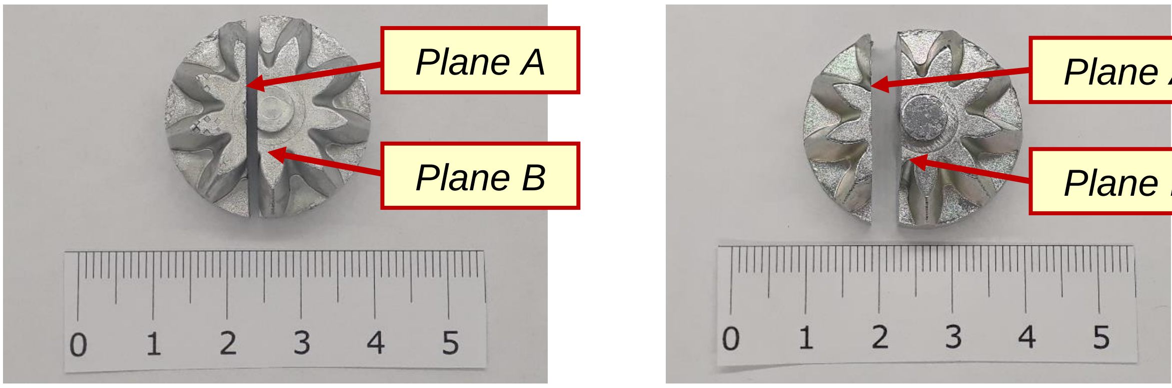
a) Right side of the casting



b) Left side of the casting

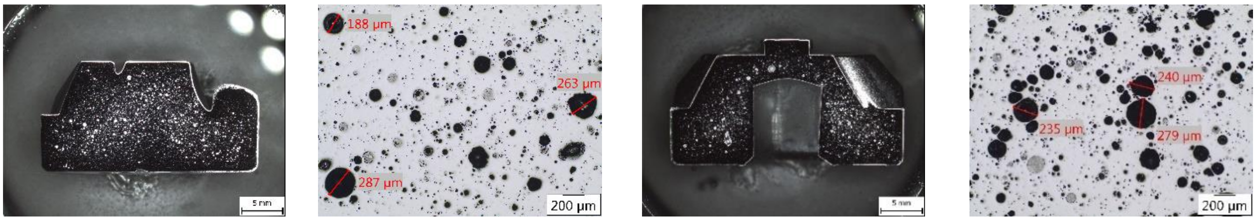
Figure 3 Computed tomography results

The last stage of methods applied for quality evaluation was analysing with the use of light metallography. **Figure 4a** shows an unworked casting No. 9 without surface treatment after its cutting by a precise metallographic saw, with areas marked plane A and plane B, which were studied subsequently by a stereo microscope and a inverted microscope (**Figure 5**). **Figure 4b** shows a metal-plated casting No. 9 with surface treatment after its cutting by a precise metallographic saw, again with areas marked Plane A and Plane B. The evaluation results using light metallography are shown on **Figure 6**.



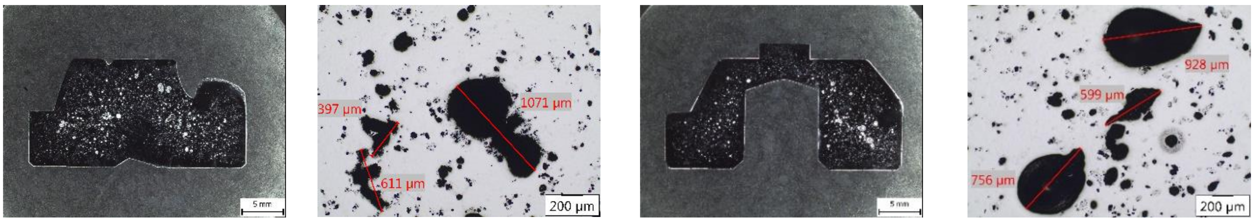
a) Raw casting **b)** Plated casting

Figure 4 Cut of castings



a) Total sample (Plane A) **b)** Sample detail (Plane A) **c)** Total sample (Plane B) **d)** Sample detail (Plane B)

Figure 5 Results of metallography of raw casting (left and right side of the casting)



a) Total sample (Plane A) **b)** Sample detail (Plane A) **c)** Total sample (Plane B) **d)** Sample detail (Plane B)

Figure 6 Metallography results of metallized casting (left and right side of casting)

4. CONCLUSION

The submitted report is focused on introduction of a potential of combined methods oriented on the study of surface and volume quality of thin-walled high-pressure die casted castings from the ZP0410 zinc alloy. Based on the above description, it is possible to state the following conclusions:

- No literature dealing in the necessary scope with the issue of zinc alloys castings quality assessment has been published in the last decades.
- Already in this stage of research activities, the roughness measuring indicates potential connections between surface quality before and after metal plating and between the castings shape.
- The computed tomography in combination with light metallography shows a significant potential for evaluation of surface and internal defects of thin-walled ZP0410 zinc alloy castings.

The described conclusions show that the selected evaluation methods, together with monitoring of a number of other technological parameters of the ZP0410 alloy thin-walled castings high-pressure die casting technology, which are not discussed in the paper, are set up in compliance with the requirements of scientific-research activities.

In the next stage, attention will be focused mainly on comparison of the studied qualitative parameters of production between castings manufactured from the primary ZL0410 raw material only, using the defined ratios of the own returnable material ZP0410.

ACKNOWLEDGEMENTS

The paper was prepared in the scope of the EPSILON programme, project TH04020055: Research and development of zinc waste recycling technology in the production of high-quality zinc alloy castings, supported from the resources of the Technology Agency of the Czech Republic.

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