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## EFFECT OF INCREASED TEMPERATURE ON DIMENSIONAL AND SHAPE ACCURACY OF CASTINGS PRODUCED FROM THE EN AC-AISI11 ALLOY BY PRESSURE DIE CASTING PROCESS

The present work discusses results of increased temperature on shape-dimensional changes of a 110 type hose coupling, produced from EN AC-AISI11 alloy with the use of pressure die casting technology. The castings were soaked for 3.5 h at temperatures 460°C, 475°C and 490°C. The verification of shape-dimensional accuracy of the elements after soaking treatment, in relation to raw casting, was carried out by comparing the 3D models received from 3D scanning. Soaking temperature of about 460°C-475°C results in no significant changes in the shapes and dimensions of the castings, or surface defects in the form of blisters, which can be seen at a temperature of 490°C.

*Keywords:* high pressure die casting, Al-Si alloy, blistering, dimensional and shape accuracy, elevated temperature behavior

### 1. Introduction

Pressure die casting technology is a very popular and cost effective method of production of large batches, especially for elements made of light metals, which should be characterized by high manufacturing precision and high quality of surface [1,2]. Nowadays, more than a half of worldwide production of aluminum alloy castings is performed in this way [3]. Such castings found their application in many various branches of industry [4,5].

The quality of an element produced with the use of pressure die casting is affected by many factors related to various parameters of casting process, including temperature of molten alloy and mould and parameters of injection [6]. Molten alloy fills the mould cavity very quickly, and then, due to rapid cooling, solidifies almost immediately. This allows the forming of a fine-grained texture of the casting, which assures good mechanical properties [5].

Various treatments are used to improve the mechanical properties of casting alloys, including adding alloying elements, modification or heat treatment. Precipitation hardening, consisting of solution, rapid cooling, natural or artificial ageing, are among the most popular methods of heat treatment used in case of silumins [7]. Components produced with the use of traditional pressure die casting are not typically soaked at increased temperatures due to the presence of numerous gaseous pores, which are trapped inside walls of a casting [8,9]. The occurrence of the pores results directly from pressure die casting, when molten metal turbulently fills the cavity the of mould, and at the same time prevents complete elimination of the gaseous phase from

cavity of the mould in a very short time, when metal is injected to the mould [9,10]. In the case of heat treatment of castings produced with the use of pressure die casting technology, soaking of the casting at high temperatures (typically, 20-30°C below eutectic temperature) and soaking it at this temperature during a predetermined period of time can result in surface blistering in the form of blowholes and deformed shape of the casting, which is due to decompression of gas trapped in the pores due to a simultaneous increase of plasticity and decrease of strength of the alloy. The initial shape and location of the pores are also important, because the blowholes located directly under the surface layer of the casting become visible at increased temperatures much more quickly than the ones located inside the casting [8,11].

In order to successfully perform heat treatment (precipitation hardening) of such type castings, it is necessary to determine the temperature of solution treatment at which no distortions could occur in the shape of the casting. The conducted tests aimed at the determination of the influence of increased temperature on the shapes and dimensions of the crowns of a 110 type hose coupling which was made in the process of pressure die casting of EN AC-AISI11 alloy. The objective of the tests was to assess the feasibility of solution treatment (T6 or T4 treatment).

### 2. Experimental Methods

The tests were performed on a casting of the crowns of a 110 type hose coupling produced with the use of pressure die casting technology (Fig. 1). The hose coupling constitutes the

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main element of any fire-fighting equipment, as a component of the pumping and suction couplings, which are used for various purposes, including couplings of quick-connectors of fire hoses and as connectors between fire hoses and fire-engines, fire-hose nozzles and hydrants. The qualitative requirements of this element are specified by the Polish standard PN-M-51031 [12].

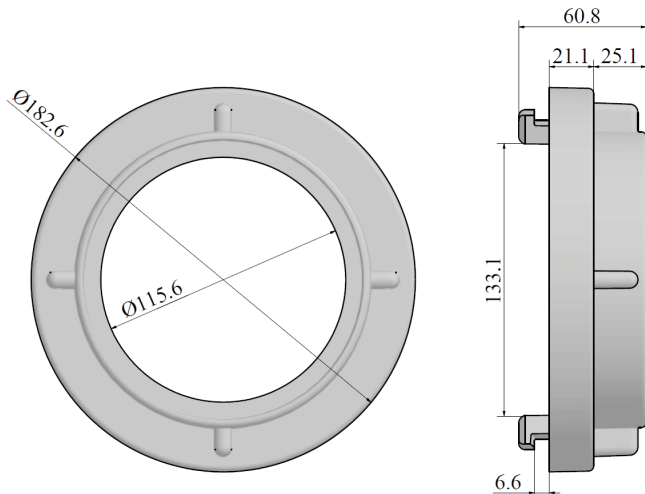


Fig. 1. Casting of the crowns of a 110 type hose coupling

The castings were produced on a cold-chamber die-casting machine from EN AC-ALSi11 alloy whose chemical composition is presented in Table 1. The chemical composition was determined on a Bruker – Q4 Tasman spark spectrometer. The metal pouring temperature was 610°C, while the metal injection pressure was 94 MPa.

TABLE 1

Chemical composition of the EN AC-ALSi11 alloy

Si	Fe	Cu	Mn	Mg	Zn	Ti	Al
10.1	0.83	0.38	0.08	0.19	0.19	0.10	rest

The castings were soaked in an electric resistance furnace at the temperatures of 460°C, 475°C and 490°C, which were determined on the basis of publications [13-16], whilst bearing in mind the limitations connected with soaking die castings at increased temperatures. The castings were soaked for 3.5 h. The temperature in the course of heating-up and soaking processes was controlled continuously, measuring the air temperature inside the furnace and the temperature of master casting (110 type hose coupling) with the use of a K: Ni-NiCr type thermocouple.

The 110 type castings of hose coupling in raw state (without heat treatment) and after soaking (at temperatures 460°C, 475°C, 490°C for 3,5 h) were scanned by 3D Heavy Duty Optima scanner (accuracy of 0.018 mm).

The next step was to verify the shape and dimension accuracy of the element after soaking treatment in relation to raw casting. This was executed with the use of the *GOM Inspect 2017* computer software, comparing 3D models obtained as a result of 3D scanning.

### 3. Results and discussion

The results presented in a graphical form (Figs 2-4) illustrate the influence of soaking temperature on the retained shape-dimensional accuracy of the casting of the 110 type hose coupling in comparison to casting without heat treatment. The green colour is used to mark the acceptable values of deviation of compared surfaces with a  $\pm 0.20$  mm difference standard, which was adopted on the basis of the appropriate standard [12].

Soaking temperature of 460°C resulted in no visible changes in the shape and dimensions of the casting in comparison with the raw casting (Fig. 2). No blisters were noticeable on the casting surface.

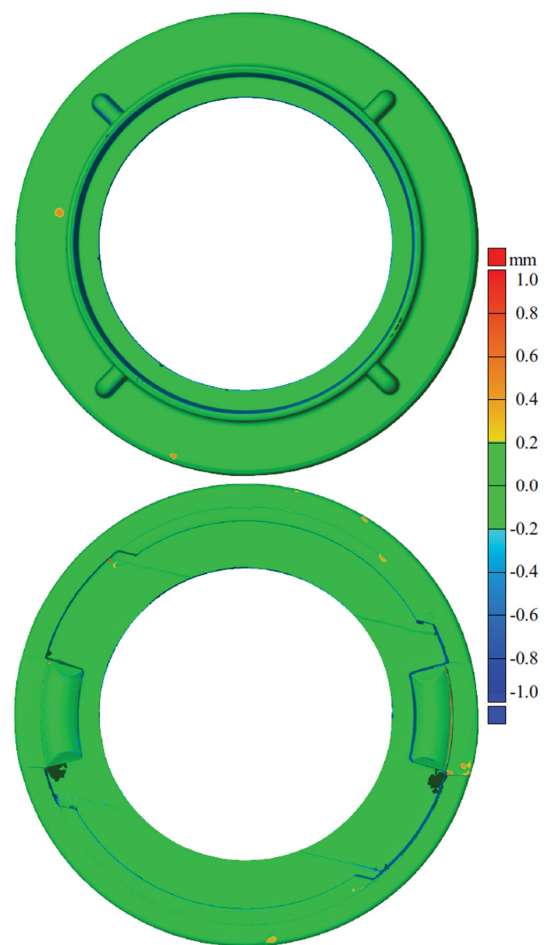


Fig. 2. Dimensional and shape transformations after soaking of the casting at a temperature of 460°C for 3.5 h

At the temperature 475°C (Fig. 3), some dimensions marked with bright yellow and bright orange exceed the permissible interval of  $\pm 0.2$  mm. However, these are not dimensions which would have an important effect on the functionality of this casting. Also, in this case no defects in the form of blisters on the casting surface were observed.

Further increase of the soaking temperature resulted in significant changes to the dimensions and shapes of the tested casting. For soaking temperature of 490°C, the surfaces marked with red and blue were considerably distorted, the distortion

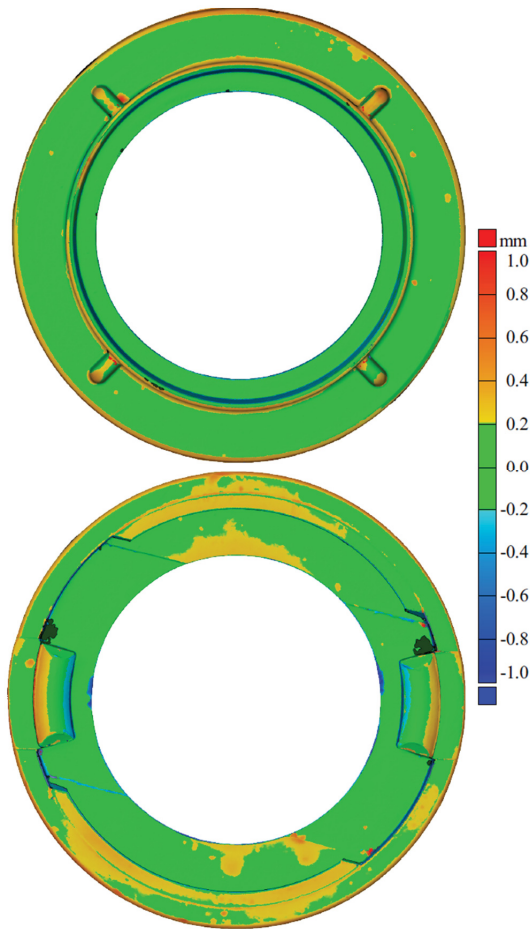


Fig. 3. Dimensional and shape transformations after soaking of the casting at a temperature of 475°C for 3.5 h

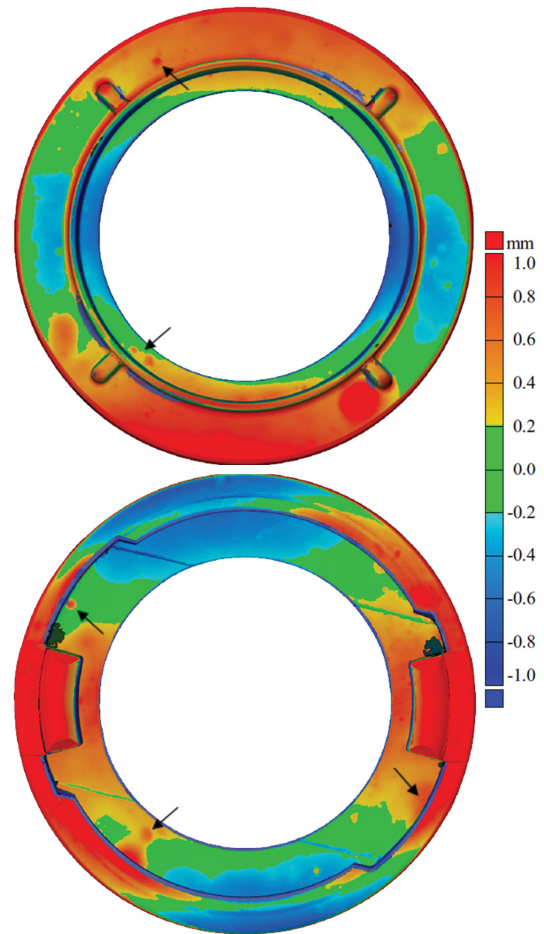


Fig. 4. Dimensional and shape transformations after soaking of the casting at a temperature of 490°C for 3.5 h

level reached nearly  $\pm 1$  mm (Fig. 4). Increased temperature also resulted in surface blisters, marked as arrows in Fig. 4.

This is caused by the blowholes trapped inside walls of the casting decrease their volume due to decompression, and at the same time, the pressure of the gas inside increases. The blisters, marked in Fig. 4, become visible as a result of the heating of the casting to a temperature which causes growth of plastic properties of the alloy and expansion of pressure of the gas locked inside the pores [8,11]. This leads directly to deformations of the walls of the casting in locations close to gaseous blowholes, which, in turn, leads to the occurrence of surface defects, expansion of gas trapped inside entire volume of the casting, as well as distortion of the shape of the casting.

#### 4. Conclusion

The obtained results of the tests with respect to retained dimensional and shape accuracy of the crowns of a 110 type hose coupling made of EN AC- $\text{AlSi11}$  alloy in pressure die casting technology lead to the following conclusions:

- soaking temperature of 460°C-475°C does not result in any significant changes in the shape and dimensions of the casting,

- increase of soaking temperature up to 490°C leads to considerable changes in the shape and dimensions, as well as in the formation of surface defects on the casting, which restricts the possibility of its usage at increased temperatures,
- potential heat treatment of the casting is possible at lower solution temperatures (460-475°C), which will allow elimination of deformation of the element shape and formation of surface blisters.

#### REFERENCES

- [1] R.N. Lumley, I.J. Polmear, H. Groot, J. Ferrier, *Scripta Mater.* **58** (11), 1006-1009 (2008), DOI: 10.1016/j.scriptamat.2008.01.031
- [2] A. Pasięka, Z. Konopka, *Arch. Metall. Mater.* **52** (2), 767-770 (2014), DOI: 10.2478/amm-2014-0129
- [3] E. Battaglia, F. Bonollo, P. Ferro, A. Fabrizi, *Metall. Mater. Trans. A.* **49A** (5), 1631-1640 (2018), DOI: 10.1007/s11661-018-4544-0
- [4] R.N. Lumley, M. Gershenzon, D.R. Gunasegaram, *Mater. Sci. Forum.* **618-619**, 331-339 (2009), DOI: 10.4028/www.scientific.net/MSF.618-619.331
- [5] M. Małysza, S. Pysz, A. Fajkiel, P. Dudek, K. Saja, M. Woś, *Transactions of the Foundry Research Institute.* **55** (4), 21-31 (2015), DOI: 10.7356/ioid.2015.19

- [6] Ł. Pałyga, M. Stachowicz, K. Granat, *Archives of Foundry Engineering*. **15** (2), 85-90 (2015), DOI: 10.1515/afe-2015-0044
- [7] J. Pezda, *Archives of Foundry Engineering*. **15** (1), 75-78 (2015), DOI: 10.1515/afe-2015-0013
- [8] A. Białobrzeski. *Odlewnictwo ciśnieniowe maszyny, urządzenia i technologia*, WNT, Warszawa (1992).
- [9] H. Toda, P.C. Qu, S. Ito, K. Shimizu, K. Uesugi, A. Takeuchi, Y. Suzuki, M. Kobayashi, *Int. J. Cast Metal. Res.* **27** (6), 369-377 (2014), DOI: 10.1179/1743133614Y.0000000123
- [10] X.G. Hu, Q. Zhu, S.P. Midson, H.V. Atkinson, H.B. Dong, F. Zhang, Y.L. Kang, *Acta Mater.* **124**, 446-455 (2017), DOI: 10.1016/j.actamat.2016.11.032
- [11] O. Ozhoga-Maslovszkaja, E. Gariboldi, J.N. Lemke, *Mater. Design*. **92**, 151-159 (2016), DOI: 10.1016/j.matdes.2015.12.003
- [12] PN-M-51031. *Sprzęt pożarniczy. Łączniki do węży pożarniczych*. PKN, Warszawa (2015).
- [13] R.N. Lumley, R.G. O'Donnell, D.R. Gunasegaram, M. Givord, *Metall. Mater. Trans. A.* **38A** (10), 2564-2574 (2007), DOI: 10.1007/s11661-007-9285-4
- [14] A. Mandal, M.M. Makhlof, T. Indian I. *Metals*. **62** (4-5), 357-360 (2009), DOI: 10.1007/s12666-009-0076-z
- [15] G. Timelli, O. Lohne, L. Arnberg, H.I. Laukli, *Metall. Mater. Trans. A.* **39A** (7), 1747-1758 (2008), DOI: 10.1007/s11661-008-9527-0
- [16] M.C. Srivastava, O. Lohne, *Int. J. Metalcast.* **10** (4), 556-565 (2016), DOI: 10.1007/s40962-016-0049-z