INFLUENCE OF DIE CASTING FACTORS AND OF HARDENING TEMPERATURE UPON MECHANICAL PROPERTIES OF A DIE CAST

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In case of production of die casts utilizable especially in expansively growing automotive industry, the particular attention is devoted to a goal-oriented increase of commercial and utility properties of a product in with acceptable economical costs. In the experimental part of the submitted paper the influence of technological factors of die casting and of hardening temperature upon mechanical properties of die casts produced from the EN AC47100 alloy represented by permanent deformation, porosity and HRB hardness were performed. On the basis of performed experiments the influence of monitored factors upon final cast quality can be stemmed from.

KEYWORDS

die cast, technological factors, hardening temperature, mechanical properties

1 INTRODUCTION

Die casting is frequently used process of production of non-ferrous casts for automotive industry. The fluid metal is forced into a mould cavity in the course of several stages. In case of the last stage the porosity can be reduced by means of resistance pressure and trough reduction of basic dimensions of pores. With regards to high speed of mould cavity filling and to rapid solidification of the melt, the process allows production of casts which are complicated as to shape. Thus the process of cast production often employs non-ferrous alloys of aluminium, magnesium and zinc. The process of die casting is characterized from the point of view die cast mould by thermal fluctuation which leads to steep thermal gradients on the surface and below the surface of a fitting piece of the die cast mould [Foldesiova 2013].

The process of die casting of metals is regulated by several significant technological parameters. Correct determination of values of the basic parameters leads to increase of the cast quality. As per the author [Allo 2013], the parameters which show enormous influence upon the die casting process can be adjusted so that by means of diverse intensity levels and by means of diverse process adjustment the economic efficiency of die cast production is assured. The performed studies present main technological parameters of the process which are divided into four basic categories [Gaspar 2014]:

- parameters related to pressure machine,
- parameters related to filling chamber,
- parameters related to casting mould,
- parameters related to cast alloy.

Hardening represents precipitation process which is performed in several stages. Precipitation occurs in case of disintegration of non-steady heavily supersaturated solid solution at relatively low temperatures. Precipitation is regulated elimination of the phase in the volume of grains in the form of precipitates – in the shape of balls or in the form of plates. Their dispersion (i.e. number and size) determines final properties of the structure [Korenko 2015]. Precipitation represents basic mechanism of heat treatment of alloys. The principle of precipitation represents also the basis of aluminium alloy hardening. In case of hardening the strength and toughness increase at the expense of tensibility [Majernik 2016]. The reason can rest in fact that precipitates are located in grains on the slip planes by means of which they prevent slips in case of deformation – they reduce tensibility. Basic precondition to be met prior to hardening rests in the change of solubility of the admixture in basic metal. Therefore the possibility of formation of supersaturated solid solution occurs, the further variation of which causes desired change of properties [Mascenik 2012].

2 EXPERIMENTAL METHODOLOGIES, EMPLOYED QUIPMENT

Testing casts (Fig. 1) made of aluminium alloy EN AC 47100 were cast in two series with the utilization of a die casting machine with horizontal cold filling chamber of the Müller Weingarten 600 type. In case of series A and series B the basic casting parameters according to Table 1 were pre-set. Chemical composition of experimental melting is shown in Table 2 and accords with the EN 17026 standard [Gaspar 2012 and 2016].

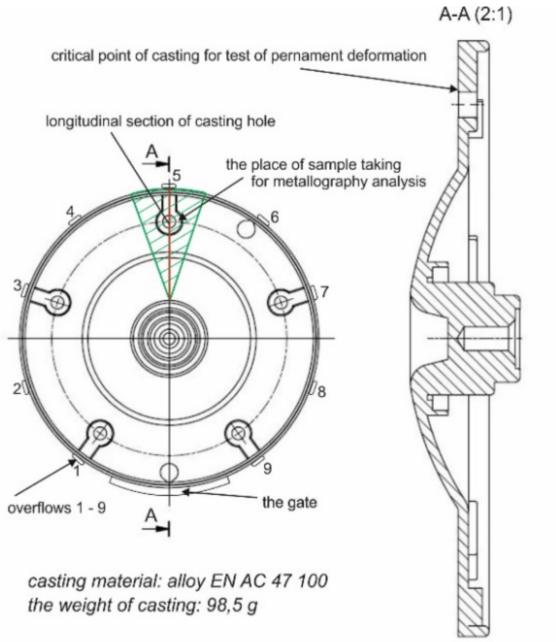

Figure 1. Experimental samples – flange of alternator

Table 1. Pre-set basic technological parameters of casting

	Series “A”	Series "B"
Pressing speed of a piston	2.5 m.s^{-1}	2.0 m.s^{-1}
Resistance pressure	30 MPa	35 MPa
Temperature of alloy	640 °C	650 °C
Temperature of mould	220 °C	220 °C
Diameter of pressing chamber	70 mm	70 mm
Height of metal residues in the chamber	25 mm	25 mm

Table 2. Chemical composition of alloy according to EN 1706 standard

Chemical composition of the experimental cast of the applied alloy % of elements content					
Al	***Si***	***Fe***	***Cu***	***Mn***	***Mg***
85.27	12.02	0.71	1.19	0.21	0.13
according to EN 1706 standard					
rest	10,5 - 13,5	max. 1.5	0.7 - 1.2	max. 0.55	max. 0.35
Cr	***Ni***	***Zn***	***Pb***	***Sn***	***Ti***
0.02	0.02	0.35	0.02	0.03	0.03
according to EN 1706 standard					
max. 0.1	max. 0.3	max. 0.55	max. 0.2	max. 0.1	max. 0.2

By means of random selection performed 96 hours after casting the non-machined casts out of both series were divided into four groups (A.1 – A.4, B.1 – B.4). The groups of casts A.2 - A.4 a B.2 - B.4 were subjected to hardening at temperature of 130°C, 150°C and 170°C during the period of 6 hours in the HS 31A furnace. Groups A.1 and B.1 were not hardened. The experimental samples were subjected to static tensile test with the use of the equipment of Tirates 28200. Measuring of hardness of testing samples was realized with the use of a hardness tester Rockwell EB-1. The area of the highest possible risk of potential malfunction in case of die casting is represented by the fastening holes – the critical points of the cast as Fig. 1 shows, which serve for fixation of a cast by means of a screw and therefore according to the GME 06007 standard the conditions for their testing are pre-set. The means of assessment of permanent deformation was performed according to the GME 60156 standard. Pressure load was of 16 kN and in case of half load amounting to 8 kN permanent deformations occurred. According to prescribed values of the GME 06007 standard the value of permanent deformation should reach the value of $s_{max.}$ = 0.150 mm. Measuring of hardness was realized in accordance with the STN EN ISO 6508-1 standard with the ball diameter of 1/16" (1.59mm) which was under the load of 950N. The macroscopic analysis assessed the longitudinal cuts of the cast holes in the point of loading during the monitoring of values of permanent deformation (Fig. 1). The porosity analysis f of scratch patterns in case of samples was realized by microscope OLYMPUS GX51 with enlargement of 100 times and processed by the computer programme of ImageJ which from the point of monitoring assessed percentage share of porosity (Fig.2).

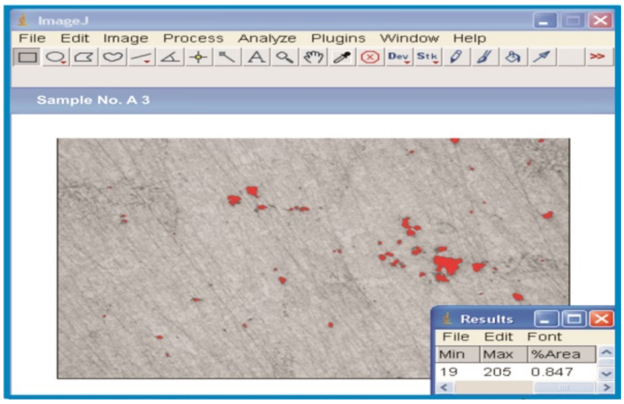

Figure 2. Determination of porosity f of sample No. A. 3 by the software ImageJ – porosity of 0.85%

3 EVALUATION OF MECHANICAL PROPERTIES

Table 3 presents average values of mechanical properties as follows: of permanent deformation "s", of porosity "f" and of hardness "HRB" in relation to determined technological parameters of casting and of hardening temperature.

Table 3. Values of Mechanical Properties

SERIES "A"				
Group of casts	Hardening temperature [°C]	Permanent deformation "s" [mm]	Porosity "f" [%]	Hardness "HRB"
A.1	Ambient temperature 22.5	0.151	1.58	55.3
A.2	130	0.135	1.11	56.2
A.3	150	0.095	0.85	58.4
A.4	170	0.072	0.79	66.3
SERIES "B"				
Group of casts	Hardening temperature [°C]	Permanent deformation "s" [mm]	Porosity "f" [%]	Hardness "HRB"
B.1	Ambient temperature 22.5	0.123	1.05	58.1
B.2	130	0.096	0.82	58.6
B.3	150	0.083	0.72	60,4
B.4	170	0.064	0.61	68.5

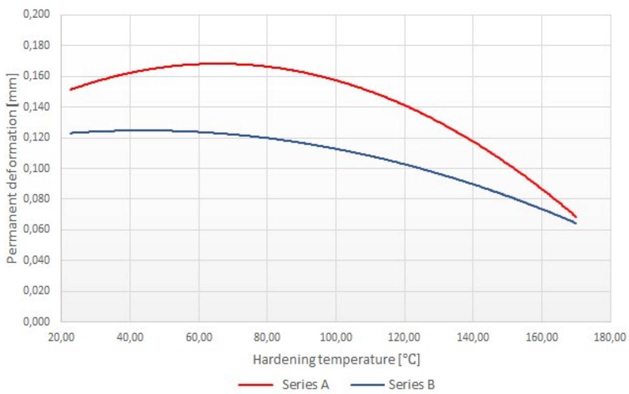

Figure 3. Dependence of permanent deformation and hardening temperature

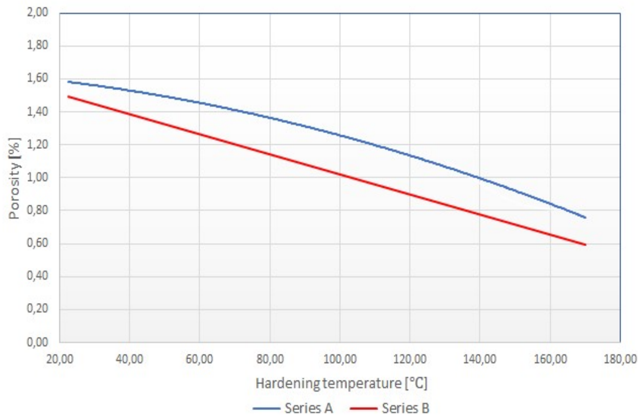

Figure 4. Dependence of porosity and hardening temperature

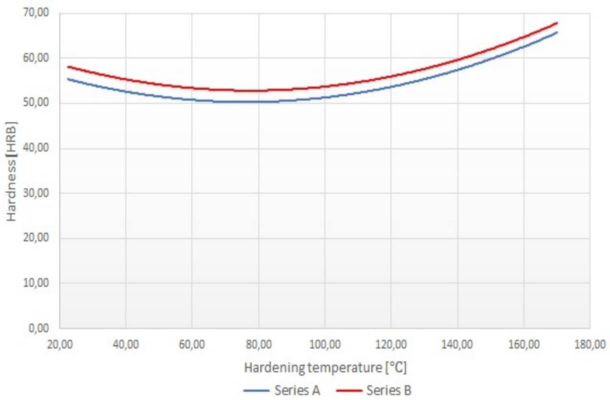

Figure 5. Dependence of hardness and of hardening temperature

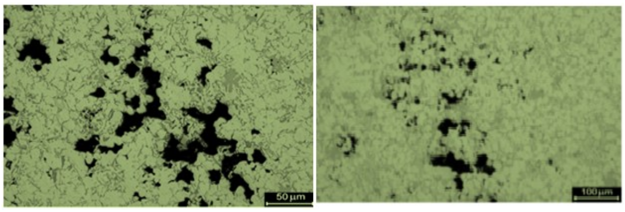

Figure 6. Sample microstructure – A Series

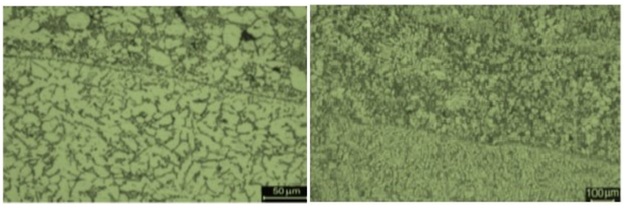

Figure 7. Sample microstructure – B Series

4 ACHIEVED RESULTS AND THEIR ANALYSIS

The measured values of permanent deformation as present in Table3 show considerable differences between standard value of s_{max} = 0.150 mm. In case of casts of the A series, the values of the A.1 series related to permanent deformation without thermal hardening represented the maximal value border and diameter amounted to s = 1.151 mm which exceeds the standard value. In case of B series the measured values of the permanent deformation did not exceed the standard value. The measured values of permanent deformation prove that the mould filling during casting of the B series casts was performed smoothly and the technological parameters of casting were satisfactory. The crucial parameter was the piston speed in the filling chamber which determined the filling mode inside the mould cavity and in its individual parts. There exists a presumption that the reason of diverse values of permanent deformation rests in air bubbles enclosed in the middle part of the fixation hole created by means of a metal core. After pressing the metal in the filling chamber the melt at high speed enters the mould cavity. The metal jet flows off the metal cores and by means of turbulent flowing it overthrows the air off the mould cavity and encloses it in the cast body in the middle part in the form of air bubbles. The permanent deformation values depend on size and on distribution of bubbles. These could be observed in case of the A series at piston speed of 2.5 $m.s^{-1}$. In case of the B series and at piston speed of 2.0 $m.s^{-1}$ the air bubbles should have been of larger dimensions and of smaller extent, on the basis of measured values. The presumption was proved even by the microstructures of samples, Fig. 7. Microstructures as shown in Fig. 7 represent the case of laminar filling. After formation of the primary crust in case of the metal core due to rapid cooling the crust remains on the core and between the crust and further part other melt jet of different microstructure is forced (cold joints). The air in the flange area and in minimal distance from the core is not enclosed in the cast body. Fig. 6 shows microstructures of samples of the analysed cast from the A series in case of which the highest values of permanent deformation was measured the causes of which represented by the air bubbles (porosity). Diverse values of permanent deformation shown in Table 1 accord with the microstructures and with the values of porosity. In case of casts which were subjected to heat expansion (hardening) the unambiguous influence upon the monitored values of mechanical properties was proved. After hardening the casts showed lower values of permanent deformation, which is shown in graph in Fig. 3. The temperature and hardness increased simultaneously, which is shown in Fig. 5. The highest hardness values were measured at hardening temperature of 170°C in case of both series. All of the measured values of permanent deformation after hardening conform to the prescribed standard value of $s_{max.}$ = 0.150 mm.

CONCLUSION

The measured values of permanent deformation of the fixation holes of the analysed casts proved that significant parameter of die casting of metals from the point of view final quality is represented by speed of mould cavity filling determining the mode of the mould cavity filling and that depends on piston speed in the filling chamber, on the size and on the means of mouthing of the gate into the mould cavity and on the mould venting. The achieved results also proved the influence of hardening upon the values of mechanical properties. Hardening appeared to have unambiguously positive impact upon values of permanent deformation, porosity and hardness of die casts. It results in increase of effectiveness and of quality of production by means of reject rate of produced die casts with positive reaction in economic field.

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