Technological Aspects of Returnable Material Introducing within Die Casting Technology

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***Abstract* – Recent survey in manufacturing of aluminium alloy casts, which are now deeply implemented into fast developing car, shipbuilding and aviation industries, is focused on increasing of utility and quantitative properties of a cast to gain its high levels of mechanical properties at reasonable costs. One way how to minimize manufacturing costs is using returnable material at the manufacturing process. The submitted paper deals with an analysis of influence of the percentage proportion of returnable material in a batch on technological manufacturing of aluminium alloy casts. In the experimental part are described the performed experiments aimed to analyse returnable material impact to cast quality represented by monitored mechanical property – a permanent „s" deformation.**

***Keywords* – Die casting, returnable material, cast quality.**

1. Introduction

Die casting represents a way of accuracy casting of a melted metal into a pressure mould under high pressure. Therefore, it is a cast technology where metalostatic pressure on a melted metal (during gravity casting) is replaced by a pressure of a wring piston in a space of a filling chamber within values from 2 to 250 MPa. [1] Then, the melted metal is pushed by the wring piston from the filling chamber of a pressure casting device through a system of mouth canals and notches into a chamber of the pressure casting form. The melted metal is injected through an inlet notch (sudden narrowed place of an inlet) into the pressure form under a very high velocity (up to 100 m.s^{-1}). [2, 3]

The die casting especially of aluminium alloys is one of the most productive technologies for manufacturing of mass series manufactured thin-walled aluminium parts. Therefore it is very extensively used in a car industry (engine, gear, differential blocks). Along with high productivity compared to other technologies it can offer high accuracy, very good surface quality, fine-grained structure without draws neither micro-draws with good mechanical properties. [4]

2. Returnable material at die casting technology

The returnable material consists of residues from chambers (both cold and hot), from inlets, lugs or malformations and other foundry accessories used at die casting technology. Calculation of returnable material volume also has to contain material loss due to metal loss during melting or spattering, then waste of splinter and scabs during casts cleaning, etc. [5, 6]

According to the survey results, some recommendations for maximum acceptable percentage amounts of the returnable materials at liquid metal preparing and manufacturing, can be accepted. [7] The returnable material prior to loading to an alloy has to be degreased, cleaned and separation agents of oil origin should be removed as well. According to the experience from practice, ratio of the returnable material depending to size of a cast is from 20 % of gross cast mass at big casts up to 75 % at small casts. When talking about devices with the cold chamber, it is up to 65 % of liquid metal mass, and with devices with the hot chamber the value is up to 50 %. At zinc alloys and ratio of the returnable material above 50 % there are some problems to maintain alloy quality. [8, 9]

It is necessary to sort returnable material carefully. Malformations and inlet systems are considered to be clean returnable material. Residuals from filling chambers, spattered alloys swept from the floor and

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malformations polluted by oil belong to contaminated material. [1 ,4]

In common practice both pure and contaminated material is loaded into the furnace, it melts, a new alloy is added in small blocks in amount depended on average amount of liquid metal and then it is refined. For contaminated returnable material it is better to use its own furnaces and after refining to use the metal – depending to gained purity – either for normal casts or, when quality is lower, for „unassuming“ casts. In any case, it is necessary to load liquid metal after refining, not directly returnable material which means fluctuation of temperature and occurring of drops in the casts. If the foundry prepares alloys from pure metals, the optimal process is to melt pre-alloy, then pure basic metal and returnable material or other waste. An express chemical, optimally spectrographic analysis is needed. Then it is possible to supplement the furnace with this alloy. If it is impossible to check the alloys composition during the manufacturing, the alloy is cast into the blocks, then the composition is analysed which is corrected during next melting. [3 , 10]

3. Experimental methods, used devices and materials

For performing the experiments, semi-automatic pressure casting machine with a cold horizontal positioned filling chamber by a German producer Muller Weingarten 600 was used. The alloy intended for casts applicable in the car industry with type indication EN AC47100 was used. Chemical composition of experimental meltages depending on percentage ratio of the returnable material in the loading was specified by a spectrometer SPECTROCAST. The chemical composition of the alloy EN AC47100 according to the standard EN 1706 (STN 424310) is shown in Table 1. For impact of returnable material ratio to technological aspect of casts manufacturing in die casting foundry analysis, casts of a flange of pumps used in car industry were used. (Fig. 1.).

Table 1. Chemical composition of alloy according to EN 1706

Al	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Pb	Sn	Ti
according to EN 1706 (STN 424310)											
rest	10.5 - 13.5	max. 1.5	0.7 - 1.2	max. 0.55	max. 0.35	max. 0.1	max. 0.3	max. 0.55	max. 0.2	max. 0.1	max. 0.2

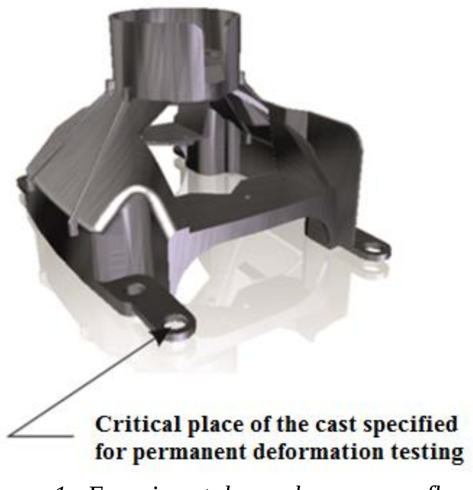

Figure 1. Experimental sample – a pump flange

The quality of the cast was represented by a mechanical property – an „s“ permanent deformation. The „s“ permanent deformation tests were performed on a testing device TIRAtest 28200. The values of the permanent deformation were monitored on a specified assembly place of the cast, Fig. 1. (so called critical place of the cast due to power load on the assembly hole and on the base of the run around of the alloy flow around the inserted core in the form of a chamber to create a hole). Permanent deformation measuring was carried out in accordance to GME 06 007 and 60 156 GME standards.

During performing the experiment, constant and variable technological factors were specified. Their impact on technological and economic aspects of the aluminium alloy die casting manufacturing was monitored.

Constant technological factors:

- pressing speed: 2.6 $m.s^{-1}$
- holding pressure: 25 MPa
- alloy temperature: 705 ºC
- mould temperature: 200 ºC
- pressing chamber diameter: 80 mm
- metal residual height in pressing chamber: 25 mm

Variable technological factors:

- ratio of returnable material in the load: 0, 10, 20, 30, 50, 70, 100 %

The cast was moulded from seven meltages with various proportion of pure and returnable materials (Table 2.). Five pieces of experimental specimens –

casts (the pump flange) from each of the meltages were randomly selected where qualitative manufacturing indications represented by mechanical properties depending on the ration of returnable material in the load were monitored.

Table 2. Experimental meltages – ratio of pure and returnable ,material

Meltage No.	Pure material	Returnable material
	Ratio	
Meltage 1	100 %	0 %
Meltage 2	90 %	10 %
Meltage 3	80 %	20 %
Meltage 4	70 %	30%
Meltage 5	50 %	50 %
Meltage 6	30 %	70 %
Meltage 7	0 %	100 %

4. Permanent deformation analysis

According to the standard GME 06007 depending on the geometry of the experimental samples the following values were specified: F_a = 16 kN, F_m = 8 kN, loading speed v_{load}. = 10 mm.s^{-1}. Following regulated values of GME 06007 the permanent deformation for a specified testing place has the value *s* = 0.025mm, which means 0.5% of the length of the fixing orifice l = 5 mm.

Table 3. shows measured values of the permanent deformation depending on the percentage ratio of the returnable material on the load. Fig. 2. presents relation of average values of the permanent deformation depending on the percentage ration of the returnable material on the load.

Table 3. Measured values of the permanent deformation depending on the percentage ratio of the returnable material

Sample No.	Ratio of returnable material on load	Permanent deformation *s* [mm]	Arithmetical average	Sample No.	Ratio of returnable material on load	Permanent deformation *s* [mm]	Arithmetical average
A 1-1	Meltage 1: pure material - 100 % returnable material - 0%	0.013	**0.013**	A 5-1	Meltage 5: pure material - 50 % returnable material - 50%	0.033	**0.036**
A 1-2		0.011		A 5-2		0.036	
A 1-3		0.014		A 5-3		0.035	
A 1-4		0.016		A 5-4		0.038	
A 1-5		0.012		A 5-5		0.037	
A 2-1	Meltage 2: pure material - 90 % returnable material - 10%	0.018	**0.016**	A 6-1	Meltage 6: pure material - 30 % returnable material - 70%	0.039	**0.043**
A 2-2		0.014		A 6-2		0.041	
A 2-3		0.019		A 6-3		0.045	
A 2-4		0.014		A 6-4		0.042	
A 2-5		0.015		A 6-5		0.044	
A 3-1	Meltage 3: pure material - 80 % returnable material - 20%	0.020	**0.020**	A 7-1	Meltage 7: pure material - 0 % returnable material - 100%	0.057	**0.052**
A 3-2		0.019		A 7-2		0.046	
A 3-3		0.022		A 7-3		0.048	
A 3-4		0.019		A 7-4		0.051	
A 3-5		0.018		A 7-5		0.058	
A 4-1	Meltage 4: pure material - 70 % returnable material - 30%	0.024	**0.023**				
A 4-2		0.026					
A 4-3		0.021					
A 4-4		0.023					
A 4-5		0.023					

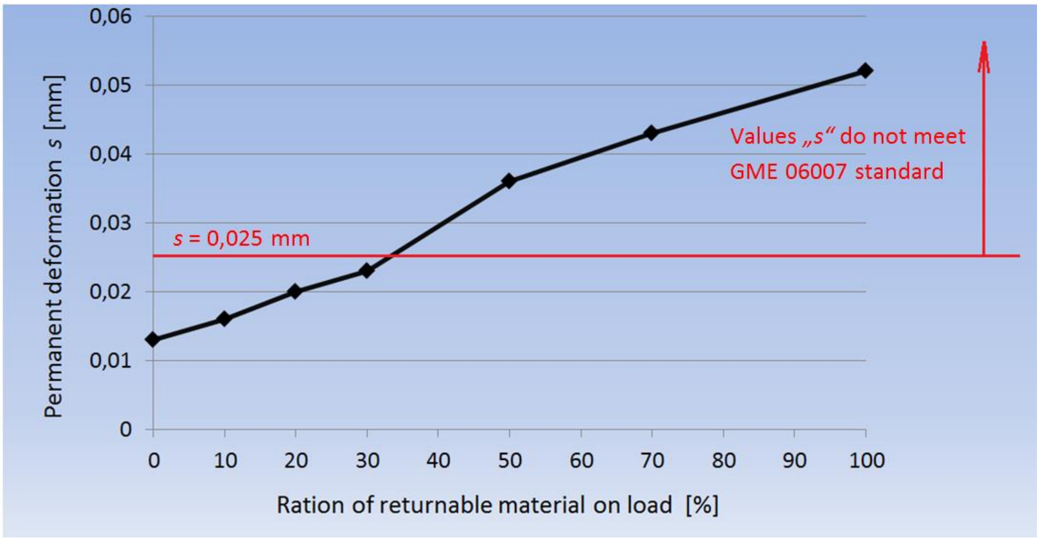

Figure 2. Relation of average values of permanent deformation depending on the percentage ratio of returnable material on load

5. Analysis of the gained results

The results during monitoring permanent deformation values depending on the percentage ration of the returnable material on the load show that the most quality casts from the point of view of the followed parameter were reached at 0 % ratio of the returnable material on the load, when the value of the permanent deformation was s = 0.013 mm. With increasing percentage ratio of the returnable material on the load, an increase of permanent deformation is registered, and thus also a decrease of mechanical properties as shown in Fig. 2. It can be said that the measured values clearly confirmed the negative impact of the returnable material on the quality of the casts which is related to its quantity in the alloy.

The measured values also show that acceptable values of permanent deformation according to GM 06007 standard (s = 0.025) were reached at 10 %, 20 % and 30 % ratio of the returnable material on the load.

On the base of the experimental results, conclusions about impact of the percentage ratio of the returnable material on the load on the technological aspects of aluminium alloy die casting can be formulated. Experimental results confirmed negative impact of increasing amount of the returnable material on the load on the mechanical properties. From the point of view of technological aspects, the recommendations for technological practice of analysed cast type can be accepted.

- ratio: pure material / returnable material
  70% / 30%

6. Conclusion

At manufacturing of the die casting products used especially at expansive rising car industry, special attention is paid to aim raising of commercial properties of a product at reasonable costs. An important aspect of quality cast manufacturing is satisfactory preparation of an alloy or load. Regarding alloy melting itself in a die casting foundry, ready alloys delivered from a metallurgical plant in a form of blocks are melted. To save costs, preparing the load from pure metals, suitable pre-alloys and certain ratio of returnable material (waste from a foundry, chips from machining etc.) is acceptable. The most quality casts during monitoring mechanical properties were reached at 0 % ratio of the returnable material on the load. But when taking into account the mechanical properties meeting the GME 06007 standard, the percentage ratio of 30 % of the returnable material on the load still secures strength characteristics set by the appropriate standard. To sum up, it can be said that specification of the percentage ratio of the returnable material on the load positively influences the technological and the economic aspects of the die casting manufacturing and it is substantial at reaching manufacturing quality indicators to minimize malformations and to optimize production economic efficiency.

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