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Effect of Selected Parameters of Pressure Die Casting on Quality of AlSi9Cu3 Castings

Ł. Pałyga, M. Stachowicz *, K. Granat
Wroclaw University of Technology, Department of Foundry Engineering, Plastics and Automation,
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 results on the effects of die-casting process on the strength parameters of castings of the aluminium AlSi9Cu3 alloy belonging to the group of EN AB-46000, made on renovated high pressure die-casting machine. Specimens for quality testing were taken from the places of the casting most loaded during the service. The aim of a research was to prove how the new die-casting process control capabilities influence on the tensile strength of the cast material defined as a value of the breaking force of the specimens. It has been found that it is possible to specify a set of recommended settings valves of second (II) and third (III) phase, which are responsible for filling the metal mould on die-casting pressure machine. From the point of view of the finished cast element, it was noticed that exceeding the prescribed values of valve settings does not bring further benefits and even causes unnecessary overload and reduce the durability of the mold. Moreover, it was noticed that reduction of the predetermined setting of the second phase (II) valve leads to the formation of casting defects again.

Keywords: Pressure die casting, Modernisation of control system, Tensile test, Strength of materials

1. Introduction

Nowadays, the most commonly met die casting machines are equipped with cold vertical pressure chambers to that metal is poured manually or automatically. In these constructional solutions, especially important for the pouring process are the phenomena occurring in the pressure chamber during operation of the working piston [1]. Typical for the above-mentioned solution are three phases of the piston operation. The first (I) phase in that the piston stroke makes only channels of the gating system filled till the inlet gap. The second phase (II) consists in filling the mould cavity and the third phase (III) consists in final pressing the metal in the mould cavity. If the first phase is not very important for final quality of the so manufactured castings, the second and the third phases are of great importance for their later long and failure-free service. Among many evaluation criteria of influence of the II and the III phases of the pressure die-casting process in cold-chamber casting machines on quality of raw castings, there are also mechanical criteria.

Mechanical examinations belong to the group of destructive testing performed on specimens specially prepared to that end, taken from the casting. This is a type of testing in that the specimens, subjected to destruction, not only enable determining strength of the casting material, but also make it possible to carry out very helpful observations and classification of the created fractures. These tests are carried-out in order to determine, in what way the material will behave under service load [2].

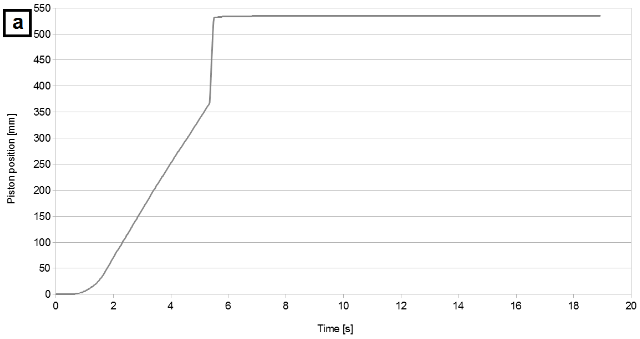
The most popular way of testing strength of materials is static tensile test. However, it should be remembered that the results obtained this way not always reflect real behaviour of a structure under load. Moreover, nowadays there is no Polish standard in force that would precise conditions of carrying-out the tensile test of parts manufactured by pressure die-casting [9]. In addition, not considered are several factors that should be taken into account during laboratory tensile test, i.e. strain rate, ambient temperature and anisotropy of the material [3,4].

It was found by analysis of the previously obtained results [5,6] that quality of the manufactured castings can be affected by technical condition of the pressure casting machine and the occurring real pressure in the hydraulic system of the machine. After modernisation and technical inspection of the cold-chamber H630-B machine made by BUHLER, a series of castings was repeatedly cast at various settings of pressure control valves in II and III phases of pouring (Table 1). In the injection system installed are 3 proportional valves with infinitely variable adjustment, permitting wide range of parameter settings. Moreover, the machine control system was equipped with a PLC controller having a function of archiving the casting parameters. The way of collecting real working pressure values is described in previous publications [5,6,7].

Table 1.
Settings of valves of II and III phases and corresponding measured values of piston speed and pouring pressure

Casting number	II phase valve opening value [%]	Measured piston speed [m/s]	III phase valve opening value [%]	Measured pouring pressure [bar]
1	10	0.3	20	245
2	10	0.3	50	290
3	10	0.3	80	345
4	20	0.75	20	245
5	20	0.75	50	290
6	20	0.75	80	345
7	60	1.2	20	245
8	60	1.2	50	290
9	60	1.2	80	345
10	80	2.3	20	245
11	80	2.3	50	290
12	80	2.3	80	345

Typical course of pouring process for the pressure die-casting machine BUHLER H630-B after modernisation is shown below [6].



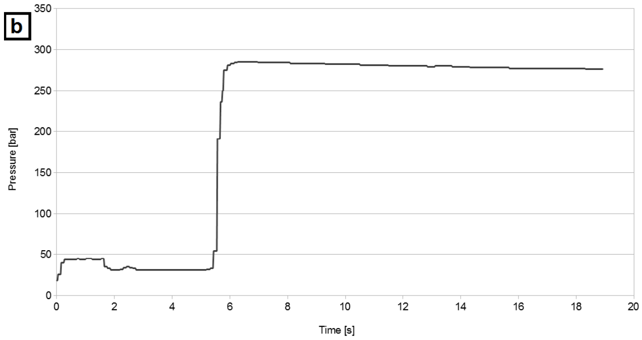


Fig. 1. Typical pouring course of pressure die-casting machine BUHLER H630-B after modernisation:
a) piston positions; b) pouring pressure

In order to evaluate influence of control parameters of a pressure casting machine in II and III phases of pouring on strength of specific products, a series of tests was carried-out on specimens taken from the casting shown in Fig. 2.

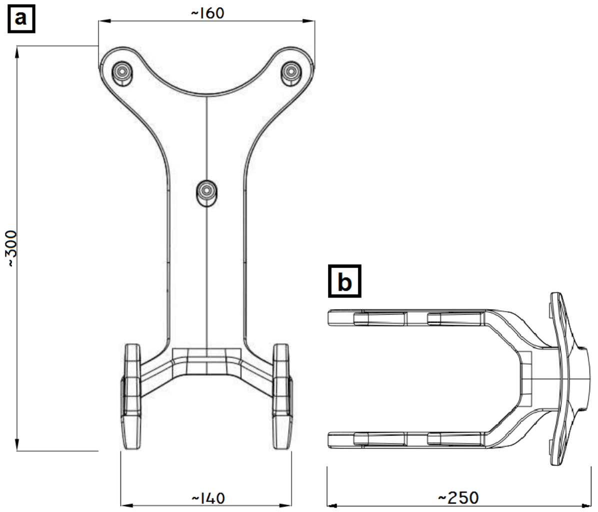


Fig. 2. Casting of a bracket: a) front view; b) top view

The castings were made of the alloy EN AB-46000 (AlSi9Cu3) [8]. According to the design assumptions, the brackets should transmit minimum load of 4000 N.

The point of force application during service of the final products is marked in Fig. 3.

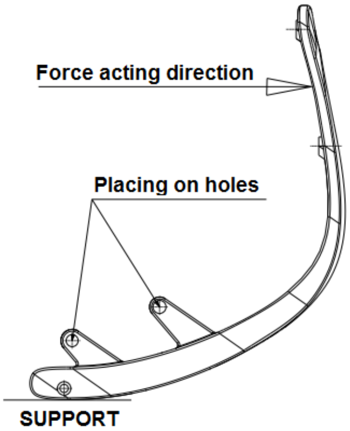


Fig. 3. Application point and direction of loading force

It should be supposed that the parts of the casting, most endangered to destruction, are its arms with the smallest cross-section area. The way and places of taking specimens from the die casting were established following the description in EN 1706:2011 [9]. Test specimens were cut-out from the arms of a bracket of the office armchair back-rest support. Figure 4a shows the place from that the test material was taken. A specimen for tensile test is shown in Fig. 4b and its dimensions are given in Fig. 4c. Because of small cross-section and curved shape of the casting, one specimen only was taken from each arm, i.e. two test specimens were prepared from one casting.

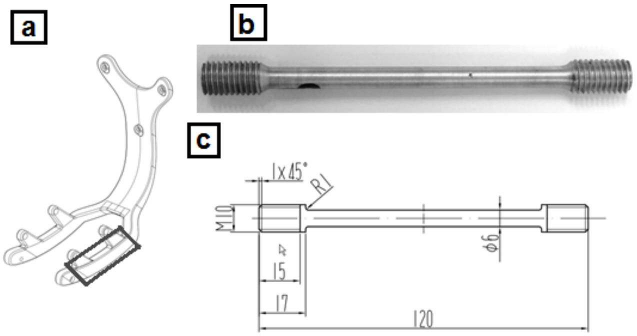


Fig. 4. Place of taking material for the test specimen (a), view of the machined test specimen (b), dimensions of the test specimen (c)

Mechanical tests were carried-out on a tensile testing machine Tinius Olsen model H25KT [10] with maximum tensile force of 25000 N.

2. Purpose of the research

Within the research, an attempt was made to determine influence of settings of pressure valves controlling operation of the piston in the pouring chamber on strength of the manufactured castings. The results are expected to determine, whether it is possible to reduce some settings of the I and II phase valves with maintained high strength and repeatable quality of the castings. Reduction of settings of the pressing assembly can favourably result in longer service life of modernised casting machines.

3. Results

Within mechanical testing measured were tensile force (N) and elongation of the specimens (mm). Each specimen was subject to tension at constant rate of 1.5 mm/min. Sampling frequency of the tensile force and elongation was 66 Hz. Accuracy of elongation measurement was 0.001 mm and that of force measurement was 0.1 N.

Figure 5 shows influence of pouring settings on maximum breaking force.

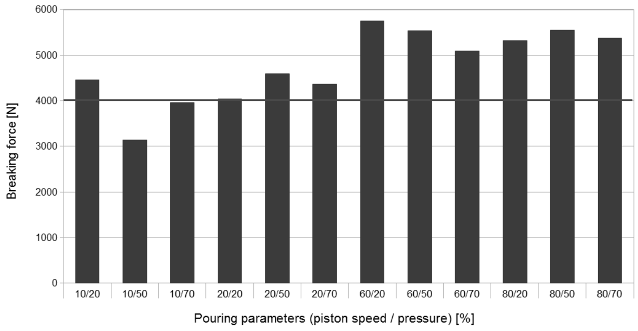


Fig. 5. Breaking force in relation to pouring parameters with marked minimum required tensile force

It was found on the grounds of the results shown in Fig. 5 that tensile strength reached the required value of 4000 N only for one casting made at low pouring rate (piston speed set below 20%). Operation of such castings could be dangerous for the users. At correct pouring rate (piston speed set to 60% and more) a sudden rise of tensile strength can be seen. The specimens with such pouring parameters reached the threshold of 4000 N and even exceeded the tension force to over 5000 N, which guarantees fulfilling quality requirements concerning strength of castings. Increase of pouring rate at constant piston speed of 1.2 m/s (60%) results in worse mechanical qualities of the manufactured castings. In the other cases, preliminary increase of pressure setting from 20% to 50% results in higher breaking force, but further rise from 50% to 70% results in lowering the breaking force.

Figure 6 shows pouring parameters and measured elongation of the specimens.

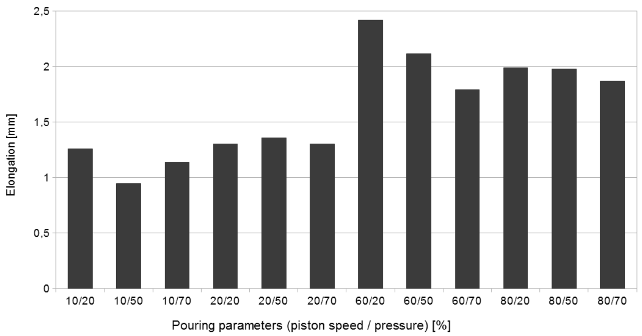


Fig. 6. Elongation in relation to settings of pouring parameters

Analysis of the results shown in Fig. 6 demonstrated that low pouring rate (piston speed set to 20% like in the case of tensile force in Fig. 5) results in fluctuation of the results between ca. 0.9 mm and 1.4 mm. However, at higher pouring rate (piston speed set to 60% or more) visible is even twofold increase of elongation. When the II phase valve is set to 60% (piston speed 1.2 m/s), the results range from 1.8 to 2.7 mm and when the valve is set to 80% (piston speed 2.3 m/s), the results are maintained at the level of 2 mm. At favourable pouring rate (the II phase valve set to 60% and more), increase of pouring pressure gives worse results.

Figures 7, 8 and 9 below show elongation of the examined specimens in relation to the tensile force. Selected were 3 specimens made at low, recommended and high pouring parameters, respectively.

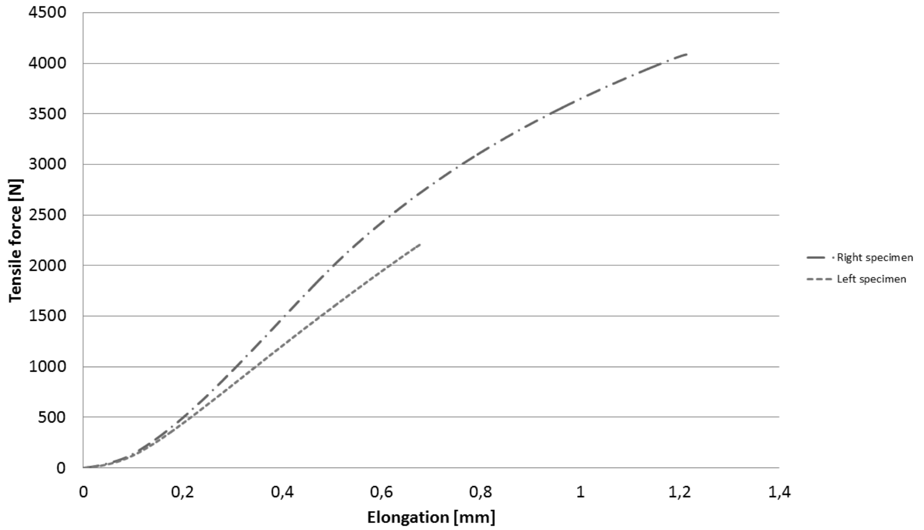


Fig. 7. Elongation of a specimen from the casting made at low pouring parameters in relation to the tensile force; pouring rate 0.3 m/s, pouring pressure 290 bar (10/50)

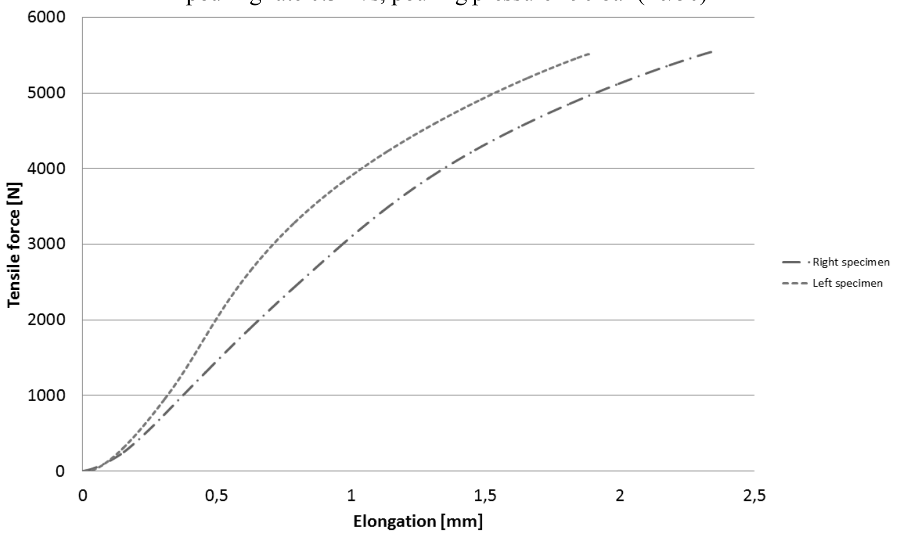


Fig. 8. Elongation of a specimen from the casting made at recommended pouring parameters in relation to the tensile force; pouring rate 1.2 m/s, pouring pressure 290 bar (60/50)

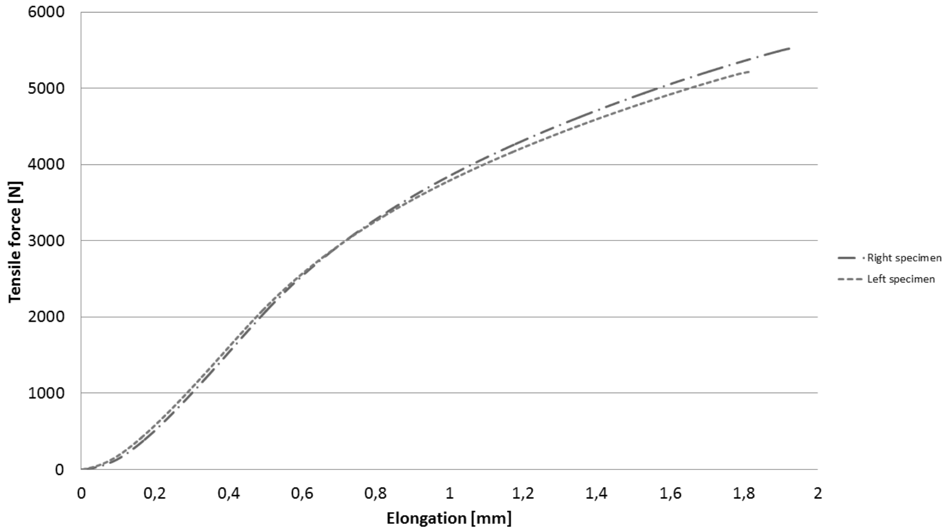


Fig. 9. Elongation of a specimen from the casting made at high pouring parameters in relation to the tensile force; pouring rate 2.3 m/s, pouring pressure 290 bar (80/50)

In Fig. 7, a clear difference can be seen between breaking forces for the left and right specimen taken from the same casting. The difference results from the fact that castings of the same series include numerous gas cavities visible on fracture surfaces of broken specimens, which additionally reduce working cross-section area of the casting arms [6,7].

Figure 8 shows the relationship between elongation and tensile force for a specimen cast at recommended settings of the valves. It was found that values of the breaking force for both specimens are close to each other, and thus more repeatable in the casting process. However, elongation of one of the specimens was almost 0.5 mm larger.

Diagrams of the relationship between elongation and tensile force for the specimens cast at high parameters (Fig. 9) are clearly similar to each other with respect to elongation and breaking force values, so it should be acknowledged that settings of the valves were most suitable to reach the highest quality of the castings and repeatability of the measured parameters.

Figure 10 shows average values of breaking force in relation to piston speed.

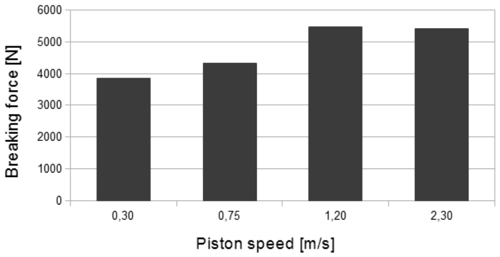


Fig. 10. Breaking force in relation to piston speed

Analysis of the data in Fig. 10 indicates that the breaking force value increases along with increasing piston speed from the initial value of 0.3 m/s to 1.2 m/s and then becomes stable.

Figure 11 shows average values of breaking force in relation to pouring pressure.

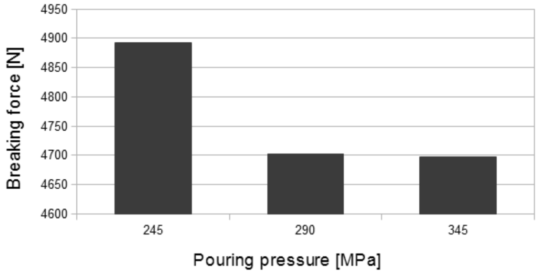


Fig. 11. Breaking force in relation to pouring pressure

Analysis of the data in Fig. 11 indicates that the most favourable pouring pressure is reached at 245 bar. In the case of that casting, this is caused by the fact that, during pouring with low III-phase value, casting defects were cumulated in the casting body (as found by observations of fracture surfaces) and thanks to that their number in the arms is significantly smaller [7].

Figure 12 shows differences between breaking force values for the left and the right specimens taken from the same casting.

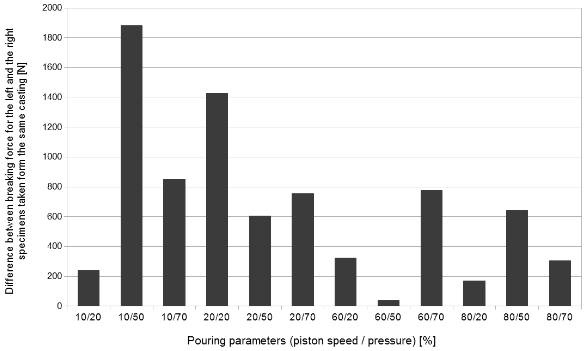


Fig. 12. Differences between breaking force values for the left and the right specimens taken from the same casting in relation to pouring parameters

It was found on the grounds of the data from the above figure that, for the specimens taken from the casting made at low process parameters, differences of the breaking force values range between 200 N and over 1800 N. The average force value for these specimens is ca. 950 N. However, for the specimens taken from the castings made at the recommended or high pouring settings, the breaking force ranges between 30 N and almost 800 N. The average force value for these specimens is 370 N.

Figure 13 shows differences between the elongation values for the left and the right specimens taken from the same casting.

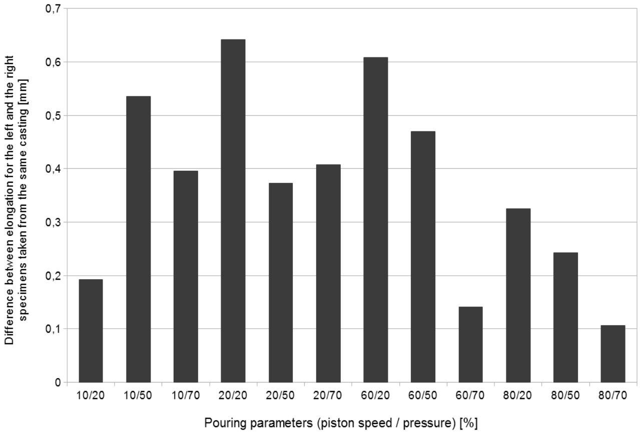


Fig. 13. Differences between elongation values for the left and the right specimens taken from the same casting in relation to pouring parameters

Analysis of the data in Fig. 13 indicates that the largest difference between the elongation values for the left and the right specimens taken from the same casting occurs in the case of the castings made at low pouring parameters. The largest difference of elongations there is over 0.64 mm. The average elongation value in this group of the specimens is 0.42 mm. For the specimens taken from the castings made at the recommended or high pouring settings, the largest difference is 0.6 mm, but the average difference in that group is 0.3 mm.

4. Conclusions

It was found on the grounds of the performed research that specialised modernisation of control system of the cold-chamber machine BUHLER type H630-B [6] entailed its high flexibility enabling easy adaptation of the most advantageous casting parameters from the points of view of both product quality and service life of the die and the casting machine.

Mechanical testing of the specimens taken from the castings made at various pouring parameters showed that tensile strength of the material can be an index of product quality.

In the case of the castings made at low pouring parameters, tensile strength of the material is lower than that accepted in the design assumptions and, moreover, the measurement results were characterised by large, even 50-% scatter of the breaking force values. These differences result from internal defects occurring in the castings (porosity) [11].

Analysis of the values of breaking force and elongation of two specimens taken from one casting shows that differences between them are the smaller, the larger is the required breaking force. Such a behaviour indicates that the mentioned parameters could be a measure of the product quality. To assess better the reason why some specimens are characterised by better mechanical properties, further research works will be carried-out on structure, material hardness and kinds of defects, and their results will be presented in the next elaborate concerning examinations of pressure castings of the alloy AlSi9Cu3.

For the casting to be examined, recommended is using the following settings of the control valve: piston speed 1.2 m/s (60%) and pouring pressure from 245 to 345 bar (20 to 70%). Further increasing the piston speed to 2.3 m/s (80%) does not give any additional advantages and will cause a reduction of failure-free service life of the modernised pressure casting machine.

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