www.czasopisma.pan.pl PAN www.journals.pan.pl

ARCHIVES of FOUNDRY ENGINEERING

ISSN (2299-2944)
Volume 19
Issue 3/2019

106 – 110

10.24425/afe.2019.129619

18/3

Published quarterly as the organ of the Foundry Commission of the Polish Academy of Sciences

Analysis of Interaction between Position of Gate and Selected Properties of Low-Weight Casts on the Silumin Basis

J. Majerník [a, *], Š. Gašpár [b]

[a] Institute of Technology and Business in České Budějovice,
Okružní 517/10, 370 01 České Budějovice, Czech Republic

[b] Technical University Of Košice Faculty Of Manufacturing Technologies With The Seat In Prešov
Bayerova 1, 080 01 Prešov, Slovakia

* Corresponding author: Email address: majernik@mail.vstecb.cz

Received 16.07.2019; accepted in revised form 06.09.2019

Abstract

Final quality of casts produced in a die casting process represents a correlation of setting of technological parameters of die casting cycle, properties of alloy, construction of a die and structure of gating and of bleeding systems. Suitable structure of a gating system with an appertaining bleeding system of the die can significantly influence mechanical and structural properties of a cast. The submitted paper focuses on influence of position of outfall of an gate into the cast on its selected quality properties. Layout of the test casts in the die was designed to provide filling of a shaping cavity by the melt with diverse character of flowing. Setting of input technological parameters during experiment remained on a constant level. The only variable was the position of the gate. Homogeneity represented by porosity *f* and ultimate strength *Rm* were selected to be the assessed representative quality properties of the cast. The tests of the influence upon monitored parameters were realized in two stages. The test gating system was primarily subjected to numerical tests with the utilization of a simulation program NovaFlow&Solid. Consequently, the results were verified by the experimental tests carried out with the physical casts produced during operation. It was proved that diverse placement of the gate in relation to the cast influences the mode of the melt flowing through the shaping cavity which is reflected in the porosity of the casts. The experimental test proved correlation of porosity *f* of the cast with its ultimate strength *Rm*. At the end of the paper, the interaction dependencies between the gate position, the mode of filling the die cavity, porosity *f* and ultimate strength *Rm*.

Keywords: High pressure die casting, Product development, Mechanical properties

1. Introduction

Even though the basis of high pressure die casting technology has been elaborated on high professional level, majority of authors got oriented in their researches towards the influence of technological parameters on quality of casts or on metallurgical preparation of alloys. Technique used in case of die casting technology frequently remains unmentioned.

In general it is true that the cast homogeneity is significantly influenced by type of the alloy flowing in the runners and mode of filling of the die cavity. Laminar flow of the melt through the runners is preferred, which whirling of the melt supporting the enclosure of air and gasses in the melt volume is eliminated. The state can be achieved by correct dimensioning of runners, by continuous transition in case of change of runner sections and without sharp change of direction of the melt flow. It is also necessary to correctly adjust the speed of the filling piston during the filling phase of die casting cycle, i.e. in the course of time before the melt reaches the gate. The change in type of flowing occurs when the melt passes through the gate. Abrupt reduction of section of the sprue and increase of speed of the filling piston during moulding stage the melt flow reaches its final speed and shape which determines the filling mode of mould shaping cavity [1][2][3].

On the basis of the aforementioned it is clear that a design proposal of gate and bleeding systems of pressure die significantly influences the quality of casts. In the monograph "Influence of Structure Adjustment of Gating System of Casting Mould upon the Quality of Die Cast" the group of authors deals with gating systems more in detail[4]. The monograph describes the influence of geometry of the gating system on homogeneity and on change of mechanical properties of casts.

In case of design proposal of a suitable position for the gate the following requirements must be taken into consideration:

- To position the gate so that the filling is accompanied by gradual rejection of the individual bleeding elements with preservation of function of the most remote bleeding spots during the last filling stage. By means of gradual filling of the die cavity formation of porosity and blow holes is predicted.
- To conduct the melt flow so that hitting the obstacles such as cores and lugs in the die cavity is avoided. The obstacles in the direction of the melt flow cause the change of mode of the die cavity filling, the blending of and the melt and consequently enclosing of gasses in the metal volume. Thus the ratio of cast inhomogeneity increases. Hitting the walls of the shaping cavity and the cores leads to reduction of kinetic energy of the melt flow and convection of heat as well as to cooling of the molten metal which can result in insufficient pouring.
- In case of casts with longitudinal holes or lugs it is inevitable to conduct the melt flow so that it is parallel with longer dimensional parameter of the die cavity.
- To select the section area so that formation of disperse flowing is avoided during the melt flowing. The blending of gasses and melt in the die cavity causes high porosity [5][6].

The assumption that different area of connection of the cast to gate causes different mode of mould cavity filling led to a hypothesis that mechanical properties and homogeneity of the casts shall be different as well. The submitted paper deals with examination of influence of the gate position on values of porosity *f* and ultimate strength *Rm* in the selected cast. Using the numerical tests using the simulation program NovaFlow & Solid, the mode of filling the mold cavity was investigated, and the prediction of the development and occurrence of porosity in individual castings was performed. The experimental tests carried out with physical casts under operation conditions verified the values of porosity achieved by numerical method. At the same time the static test of tensile strength was carried out. On the basis of the results achieved through experiments the interaction dependences between position of gate, mode of filling of die cavity, values of porosity *f* and ultimate strength *Rm* were deduced. In conclusion these dependences have been transformed to recommendations for practice, especially for structural and design stage of the development of dies. From the point of view of science they serve for clarification of dependences between the individual parameters (not possible to be merged at the first sight) and aspects of die casting.

2. Experimental Material and Methodology of Work

Numerical and experimental tests were carried out with the cast of the test bar according to ČSN 420315 standard shown in Figure 1 [8].

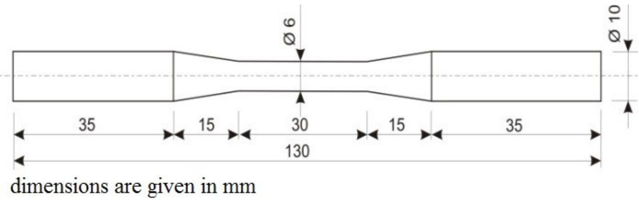

Fig. 1. Test bar 6x30 [8]

For the casting of test bars a die casting mould was used designed for casting of test bars in accordance with ČSN 420315 standard. Figure 2 shows the schematic placement of bars in the die with the gate being mouthed. The different way of the cut mouthing, its different structure and dimensions also assured different mode of filling of both the left and the right test bar. The influence of the cast shaping upon the level of inhomogeneity and upon the change of ultimate strength *Rm* was monitored. The test samples were made of alloy EN AC 47100 [9]. Chemical composition of the experimental melting is shown in Table 1. The chemical composition of the alloy was verified using the Q4 TASMAN Multibase Optical Emission Spectrometer.

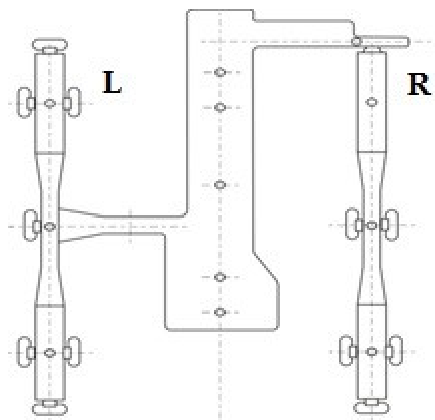

Fig. 2. Placement of casts in the die

Table 1.
Chemical composition of the experimental melting

		according to EN 1706 standard
Al, %	85.27	The rest
Si, %	12.02	10.5 – 13.5
Fe, %	0.71	max. 1.5
Cu, %	1.19	0.7 – 1.2
Mn, %	0.21	max. 0.55
Mg, %	0.13	max. 0.35
Cr, %	0.02	max. 0.1
Ni, %	0.02	max. 0.3
Zn, %	0.35	max. 0.55
Pb, %	0.02	max. 0.2
Sn, %	0.03	max. 0.1
Ti, %	0.03	max. 0.2

Realization of production of test samples was carried out using the die casting machine Müller Weingarten 600. Setting of technological parameters of casting cycle was kept on the constant level according to Table 2. These parameters were followed even in case of realization of numerical tests of the set.

Table 2.
Technological parameters of casting cycle

Parameter	Value
Speed of a pressing piston, $m.s^{-1}$	0.75
Temperature of melt, °C	660 ± 10
Temperature of die cavity, °C	220 ± 10
Time of die cavity filling, s	0.010
Holding pressure, MPa	20

Static test of tensile strength was carried out using the device of ZDM 30/10, speed of jaw shift was set up to $10mm.min^{-1}$. Assessment of homogeneity of casts was realized with scratch patterns of the samples taken off the volume of test bars. Assessment of macroscopic structure was carried out with the microscope Oplympus GX 51. Ratio of pores expressed in percentage per area of scratch patterns was determined by the program of ImageJ.

For the realization of numerical tests the 3D model of the ingate system was created by means of the program Autodesk Inventor. Simulations of the melt flowing through the gating system, cast solidification and assessment of porosity were carried out with the program of NovaFlow&Solid.

3. Simulation Test of the Melt Flowing and Assessment of Porosity

The test samples were subjected to a simulation test by means of the software of NovaFlow&Solid in order to predict occurrence of defects of casts, especially of porosity assessment. Technological factors of the casting process were set up on the constant level in accordance with Table 2. During simulation it is possible to see clearly the flow of melt and method of the die filling for both test samples. Figure 3 shows filling of the die cavity for the individual test bars.

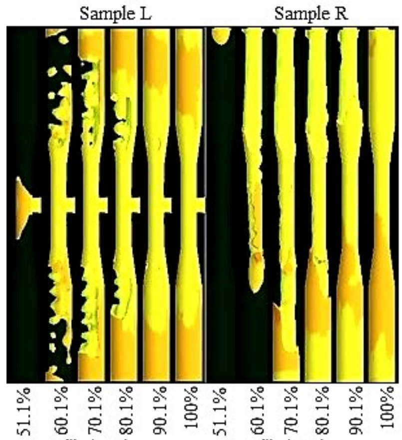

Fig. 3. Melt flowing in the die cavity

On the basis of the performed simulations it was possible to assess porosity of the individual test bars. The summary of the assessed parameters is shown in Table 3.

Table 3.
Parameters assessed in a simulation

Position	Parameter	Value
L	Time of die cavity filling, s	0.0105
	Time of cast solidification in the die, s	5.018
	Porosity, %	0.9
R	Time of die cavity filling, s	0.011
	Time of cast solidification in the die, s	5.018
	Porosity, %	5.5

4. Experimental Analysis of Ultimate Strength *Rm*

Static test of tensile strength was carried out in case of seven sets of casts. The results of stating test of tensile strength are given in Table 4.

Table 4.
Values of ultimate strength *Rm*

Sample		u. strength *Rm*, MPa	Sample		u. strength *Rm*, MPa
L bar	1	231	R bar	1	202
	2	239		2	204
	3	232		3	207
	4	235		4	209
	5	240		5	213
	6	242		6	211
	7	244		7	209
Average		237.57	Average		207.85

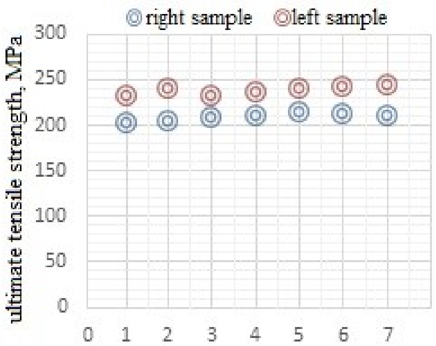

Fig. 4. Comparison of ultimate strength *Rm* of the individual samples

5. Experimental Analysis of Porosity *f*

To a relevant extent the CA programs can predict occurrence of defects of casts. To verify the results obtained by the simulation program applied in case of the examined samples the macroscopic analysis of porosity was realized. Scratch patterns were taken off several spots in the section of the test bar. As the scratch patterns were realized in several randomly selected spots of the test bar it can be assumed that the average value of percentage ratio of pores in the individual scratch patterns equals to overall value of porosity in the volume of the entire test bar. The detected results by means of scratch patterns are shown in Table 5.

Table 5.
Average percentage ratio of porosity *f*

Sample		Porosity *f*, %	Sample		Porosity *f*, %
L bar	1	0.79	R bar	1	5.32
	2	0.96		2	4.79
	3	1.23		3	5.04
	4	0.82		4	4.97
	5	1.04		5	4.86
	6	1.15		6	5.28
	7	0.91		7	5.37
Average		0.99	Average		5.09

Fig. 5 shows an example of the scratch pattern produced from the sample of L Bar – 4. Figure 6 shows an example of the scratch pattern produced from the sample of R Bar – 1.

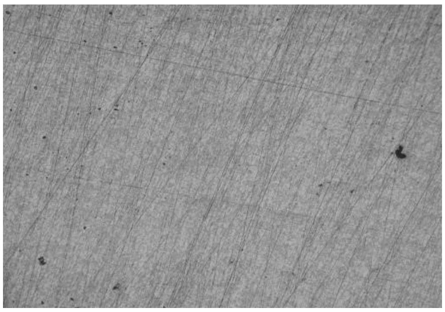
Fig. 1. Bar Sample L - 4 /x100/


Fig. 2. Bar Sample R – 1 /x100/

6. Discussion on the Achieved Results

On the basis of performed experiments it can be stated that the position of the cast in the die and its point of connection to the gating system is influenced by the values of ultimate *Rm* and porosity *f*. According to numerical tests carried out by means of simulation program and on the basis of their consequent verification by experimental test with the test samples it was detected that the values of monitored parameters were more favourable in case of samples of test bars with the left position.

The explanation of the phenomenon can be sought for in the mode of the melt flowing through the die shaping cavity. Theoretical aspects of projection of the gating systems do recommend the melt flow to avoid hitting the lugs and cores or the wall of the working die cavity after passing through the gate. At the same time it is desired to have the melt flow parallel with longer dimension of the cast by means of which it is possible to eliminate absorption of air and gasses in the die by the melt. The cast placed in the die on the right meets the aforementioned conditions yet despite this fact it shows higher values of porosity. Right the simulation can offer the explanation of negation of theoretical bases. During the filling of the right bar (Figure 3) the melt flow appears to be compact when passing through the die shaping cavity. Passing through the cavity is followed by the flow hitting the opposite side at the place of which a backward wave is formed proceeding towards the gate and pushing in front of its head the air in the die cavity to the areas with inactive bleeding (placement of bleeding holes is shown in Figure 2). By means of the aforementioned behaviour of the holding pressure is not absolute and the air remains enclosed in the cast volume which results in increased values of porosity. Vice versa, in case of bars placed on the left the melt flow hits the opposite side of the die cavity, it splits up and an abrupt spattering of the melt in the area of the working cavity occurs (Figure 3). This fact support enclosure of the air in the melt yet the melt flow is modulated so that the air pushed in front of its head is gradually released through the bleeding system out of the area of the working cavity. Placement of the bleeding holes (Figure 2) consequently allows additional displacement of the air out of the melt volume during the stage of holding pressure activity. On the basis of these facts it can be stated that the final porosity of the cast is influenced not only by the cast moulding in the die but also by distribution of the bleeding channels and holes so that their gradual ejection by the melt flow as well as preservation of their functionality is guaranteed as long as possible.

Experimental analysis of porosity confirmed assumptions obtained by means of simulation tests. It was detected that the average value of porosity *f* reached the value of 0.99% in the sample with the left position – L Sample and in the sample with the right position – P Sample it reached the value of 5.09% (Table 5). The reason has been explained above.

Ultimate strength *Rm* with the samples L Sample reached the values ranging from 230 up to 245 MP. Samples R Sample reached the values ranging from 20 up to 215 MPa (Table4, Figure 4). When comparing the values of ultimate strength *Rm* and those of porosity *f*, provable shall be their close correlation. On the basis of this fact it can be stated that ultimate strength *Rm* depends on porosity *f* of casts.

Ultimate strength *Rm* depends on porosity f and porosity *f* depends on the mode of filling of the die cavity, on the moulding of cast in the die, on the placement of gate and on the distribution of bleeding channels and thus ultimate strength *Rm* is in close interaction with described structural adjustments of the gating system.

Since the interaction of ultimate strength *Rm* and position of the gate were proved, it is possible to express an experimentally supported statement that the ultimate strength *Rm* does not represent a purely material constant stemming from the properties of casting alloy yet it depends on moulding mode of the cast and thus on the position of its connection to the gating system.

7. Conclusions

The submitted paper deals with the possibility of interaction of position of the gate of the cast and selected properties of low-weight casts. The examined properties were ultimate strength *Rm* and porosity *f*. The experiments carried out on numerical and laboratory level proved that the position of the gate influences both selected properties of the casts. By moulding of the cast as well as by the structure and placement of the gate it is possible to influence the mode of filling of the die cavity which determines tendency of absorption of air and gasses in the volume of the melt during filling. Imperfect air discharge out of the working die cavity causes increase of porosity of casts which can be consequently observed in reduction of mechanical properties, i.e. in our case the values of ultimate strength are reduced. Ultimate strength is therefore indirectly proportional to porosity which depends on air discharge out of the die cavity. Position of the runner of the cast and distribution of bleeding channels represent thus determining factors of the quality of casts.

Secondary line of the paper is comparison of the results of numerical and experimental tests. The values of porosity obtained by means of simulation program are close to actual values. This confirms the fact that the use of the CA systems in foundry industry can play significant role in pre-manufacturing stages. As the experiments proved the use of the CA support can predict occurrence of defects in casts. It is a suitable solution for optimization of structural solution of gating systems of permanent moulds as well as for optimization of setting up the parameters of die casting cycle. The use of the CA support has a direct impact on saving of time of planning and manufacturing part of the design proposal as well as on economic burden of the company occurring under influence of defective rate of manufacture and waste in case of optimization of the zero series of casts being subjected to approval process between a customer and a foundry plant.

The submitted paper examines the interaction of position of the sprue and of the values of porosity and of the ultimate strength. The team of authors conducts the research towards more complete analysis of the influence not only of the position of the gate on qualitative properties of the casts yet even towards the analysis of the influence of its geometrical characteristics on these properties with the focus on casts manufactured in a factory with practical applicability in mechanical engineering industry.

References

[1] Ružbarsky, J. et al. (2014). *Techniques of Die Casting.* Lüdenscheid: RAM – Verlag.

[2] Paško, J., Gašpár, Š. (2014). *Technological Factors of Die Casting*. Lüdenscheid: RAM – Verlag.

[3] Iwata, Y. et al.. (2012). Compression behavior of entrapped gas in high pressure diecasting. *Materials Transactions.* 53(3), 483-488. DOI: 10.2320/matertrans.F-M2011858.

[4] Gašpár, Š. et al. (2017) *Influence of Structure Adjustment of Gating System of Casting Mould upon the Quality of Die Cast.* 1st ed. Lüdenscheid: RAM - Verlag, 82 p. ISBN 978-3-942303-47-7.

[5] Majerník, J. et al.. (2017). Analysis of Influence Dimensions of the Gate on the Homogeneity of the Low Weight Castings Made of Silumin. *Manufacturing Technology.* 17(4), 499-502. ISSN 1213–2489.

[6] Cao, H. et al.. (2019). Direct observation of filling process and porosity prediction in high pressure die casting. *Materials.* 12(7), Article number 1099. DOI: 10.3390/ma12071099.

[7] Trytek, A. et al.. (2016) The Effect of a Thin-Wall Casting Mould Cavity Filling Conditions on the Casting Surface Quality. *Archives of Foundry Engineering.* 16(4), 222-226. DOI: 10.1515/afe-2016-0113.

[8] ČSN 420315. Testing of metals. Cylindrical test rods with smooth cylindrical heads for tensile testing. Prague: Office of Standards and Measurements. 1980. 4 p.

[9] ČSN EN 1706. Aluminum and aluminum alloys - Castings - Chemical composition and mechanical properties Prague: Office for Technical Standardization, Metrology and State Testing 2010. 28 p.