IMPACT OF CONSTRUCTIONAL MODIFICATION OF THE PRESSURE DIE CASTING MOLD INLET SYSTEM ON THE INTERNAL SOUNDNESS OF THE SILUMIN CASTING

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The design of the inlet system has been regarded as a major factor in the internal homogeneity of the casting. Being designed correctly, the system should ensure the proper and continuous filling of the mold cavity. Continuous filling of the cavity gives the initial prerequisite for internal soundness and homogeneity of the casting reflected in its quality and mechanical properties. The paper deals with the design of the inlet system for a particular type of the casting, its optimization using computer simulation as well as evaluation of the real results measured on the casting physical models.

KEYWORDS

pressure die casting, mold, inlet system, casting quality

1 CHARACTERISTICS OF A CASTING

The gating system was realized for a particular casting of a flange of electric motor shown in Fig. 1.

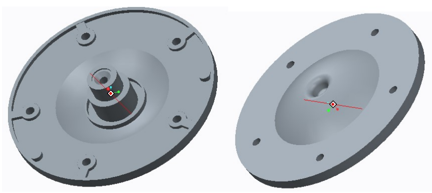


Figure 1. Casting of a flange of electric motor

According to the drawing documentation of a casting the CAD system of Pro/Engineer – Creo Parametric 2.0 was used for creating of a casting model. Through the application of respective modulus in the program the volume of a casting was determined and the weight was specified on the basis of alloy density out of which it was cast. A casting is made of aluminium alloy under type designation of EN AC 47100 – AlSi12Cu(Fe) included in the group of silumins. Table 1 presents characteristic parameters of a casting.

Table 1. Weight and volume characteristics of a casting

QUANTITY	VALUE
Volume of a casting	$51697.9.10^{-9}$
Density of an alloy	2650 kg.m^{-3}
Weight of a casting	0.136 kg

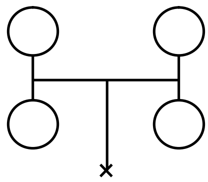
2 DESIGN OF THE GATING SYSTEM

Designing of the gating system was subjected to the defined limitations related to the type of a die casting machine. Inevitable was to take into consideration the mould size, the shaping insert, the placing of ejectors inside the mould, the structure of supports intended for the ejectors on the body of a casting and of gating channels, and the creation of buffers serving as absorbers of the initial impact of the melt flow against the walls of the mould cavity. [Gaspar 2014] The length dimensions of gating channels are designed with respect to flowing of the metal, pressure loses, the decrease of the velocity of the melt flowing through the channels, and temperature loses. [Mascenik 2012, Orlowicz 2015]

Calculation of dimension characteristics of the gating system was realized pursuant to the method elaborated by Mike Ward: Gating Manual, NADCA, USA, 2006.

On the basis of numeric calculations the Table 2 was elaborated containing the calculated values and by means of the modelling CAD system the initial model of the gating system for a casting of the electric motor flange was constructed as shown in Fig. 2.

Table 2. Calculated values of the quantities inevitable for the gating system design

PARAMETER	VALUE
Layout of shaping cavities	N.B.: following scheme was used for the layout of cavities: 
Mould cavity filling time / t	0.019 s
Ingate velocity / v_z	49.15 m.s^{-1}
Spew volume/ V_P	$19.645.10^{-6}$ m^3
Spew weight/ m_P N.B.: Proposal of volume and weight realized on the basis of North American Die Casting Association	52.10^{-3} kg
Ingate surface/ S_Z	$75.97.10^{-6}$ m^2
Ingate length/ a	$60.968.10^{-3}$ m
Ingate height/ b	$1.25.10^{-3}$ m
Lateral ingate surface / S_{KV}	$368.8.10^{-6}$ m^2
Lateral ingate height / CT	$14.59.10^{-3}$ m
Lateral ingate width / CB	$29.18.10^{-3}$ m
Lateral ingate length / l_V	280.10^{-3} m
Fillet size	$7.295.10^{-3}$ m
Inclination angle of lateral sides/ α	75°
Lateral ingate surface / S_{KH}	$811.36.10^{-6}$ m^2
Lateral ingate surface / CT_H	$14.59.10^{-3}$ m
Lateral ingate width / CB_H	$51.70.10^{-3}$ m
Main ingate length / l_H	264.10^{-3} m

The gating system in Fig. 2 is shown with the attached castings. It presents the layout and placing of the castings in the mould.

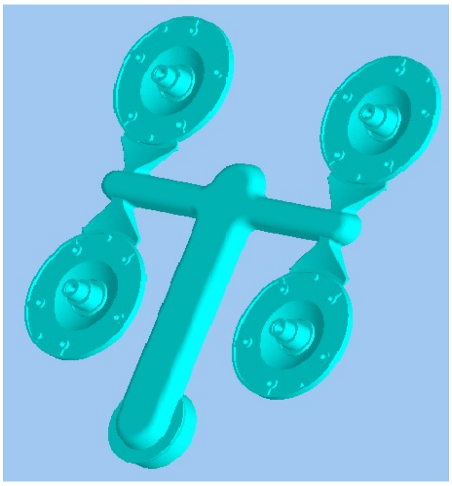


Figure 2. 3D model of the gating system

3 TEST OF THE DESIGNED MODEL

The tests of the model were simulated in the program of NovaFlow&Slolid. The program is developed by the company of NovaCast, S. A., Sweden. In testing of the primary model in the simulating program the following results shown in Table 3 were achieved with maintaining of the casting technological parameters:

Table 3. Observed parameters of a casting

PARAMETER	VALUE
Length of the process of mould cavity filling [h:m:s]	00:00:052
Solidification time for a casting [h:m:s]	00:21:567
Full volume [%]	94.6
Percentage of shrinks [%]	5.4

Simulation and visual representation proved that setting-up of technological parameters for the respective model was not suitable. Fig. 3 shows simulation representation of the gating system after die casting completion.

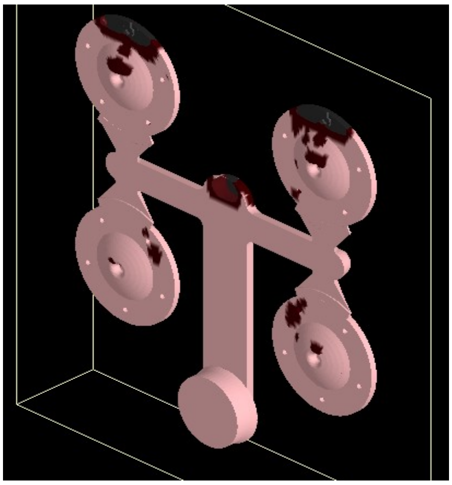


Figure 3. Simulation of calculated gating system

Percentage of shrinks related to respective casting is unacceptable. According to the initial design it is clear that section of ingate channels are extensive and the melt flow loses pressure and velocity at which the melt flow is delivered into the shaping mould cavity, i.e. liquid metal is cooled more rapidly in the gating system. On the basis of data acquired from the simulation the graph shown in Fig. 4 was drawn.

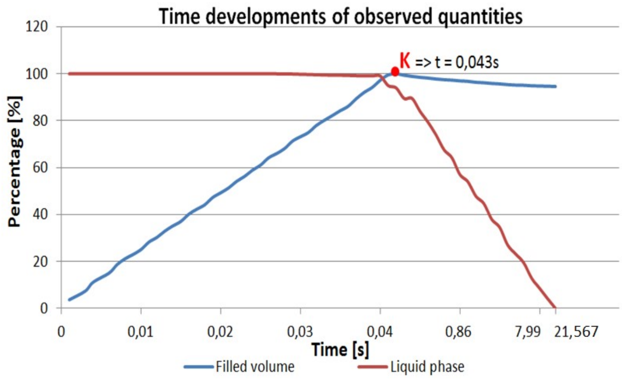


Figure 4. Time developments of observed quantities in case of the first model

The graph presents time developments of change of the mould cavity filling and percentage of liquid phase in the melt. The observed time section is set up for the period of time unless the gating system and castings are completely solid. In the K point the temperature of the melt in the gate drops below the melting point and the influence of resistance pressure and elimination of material shrinkage cannot become evident. For this reason material shrinkage and formation of shrinks in the bodies of castings occur.

Elimination of such phenomenon requires adjustment of the gating system so that total mould cavity filling time decreases. Reduction of section of ingate channels with maintaining of the alike technological conditions of the casting process results in the achievement of higher velocity of the melt flow and faster mould cavity filling by which premature solidification of the melt inside the ingate is prevented.

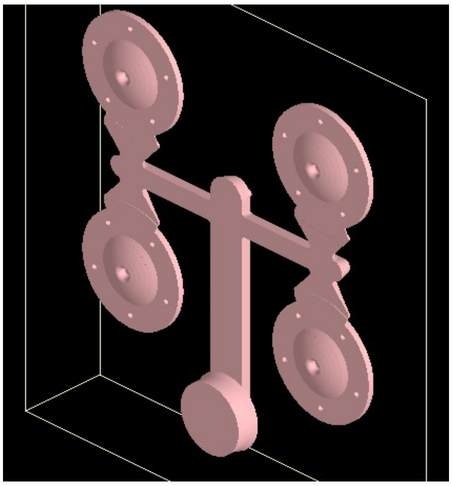


Figure 5. Final design of the gating system

Shrinks are not apparent in the bodies of the castings or inside the ingate channels. The following observed parameters were detected in the values as shown in Tab. 4.

The following graph in Fig. 1 shows developments of the observed quantities in the simulation of adjusted model. Graphical presentation of the measured values proves continual mould cavity filling. To assess the solidification process the observed parameter taken into consideration was represented by the percentage of liquid phase in the mould cavity having changed in the course of time. The parameter was observed until the material in the body of a casting changed completely into solid phase.

Table 4. Final design parameters

PARAMETER	VALUE
Length of the process of mould cavity filling [h:m:s]	00:00:043
Solidification time for a casting [h:m:s]	00:20:877
Full volume [%]	100
Percentage of shrinks [%]	0.0

By means of continual solidification of the melt inside the mould under resistance pressure the internal stress in the body of a final casting, cracks, and cold laps can be eliminated. Solidification occurs even during the process of die casting cycle and percentage of the solidified metal increases when the melt passes through the ingate channels and the gate. The simulation proved that percentage of liquid in the melt began to decrease from 0.027 s which refers to the time both of the melt penetrating through the ingate and of the start of the casting body filling. The solid occurrence is taken into consideration already in case of primary numerical design of the gating system. [Pasko 2014] Certain percentage of solidification at the end of the mould cavity filling S dependent on the wall thickness of a casting is permissible for aluminium alloys. Initial calculation counted in even 20% of solidification proportion whereas the simulation referred to 0.9% only. The cause rests in the selected initial temperature of the melt and in injection velocity, which were set up to the values higher than the standard is. The reason for overestimation was achievement of higher qualitative parameters of a casting.

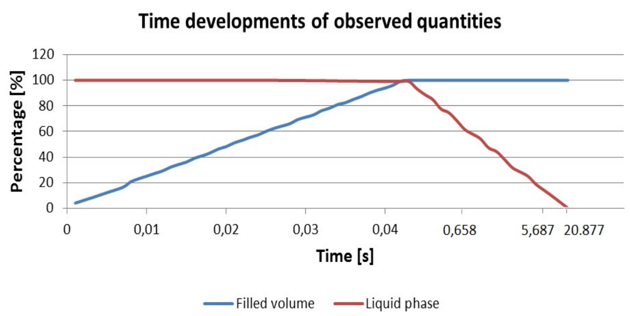


Figure 6. Time developments of observed quantities with adjusted model

Pursuant to the performed simulation, by its analysis and assessment the designed gating system, structure of ingate channels and of the gate as well as formation of the casting and its attachment to the ingate can be assumed as the suitable ones. Therefore the respective design could be passed to production, the shaping inserts for particular mould cavity shape could be produced, and a casting could be included into production of the zero series in case of which mechanical tests shall be performed to detect qualitative and mechanical properties of a casting. The designed gating system and a respective casting cast by the die casting machine with type designation of Müller Weingarten 600 intended for die casting of non-ferrous metals. The machine is equipped by three-phase injection system with a multiplier and press-button control. The main technological parameters are presented in the following Tab. 5.

Table 5. Parameters of die casting machine

Parameters of die casting machine Müller Weingarten 600	
Dimensions (w x h x l)	2 x 3.2 x 8.7 m
Weight	27t
Motor performance	37kW
Locking force	600t
Injection force	65t
Ejecting force	35t
Min./max. mould height	400-900 mm
Max. weight of Al casting	12 kg

Analysis of porosity f was carried out by the microscope of OLYMPUS GX51 with magnification of 100 times. The assessment of the samples was realized by the computer program of ImageJ which assessed the percentage of porosity of the observed location. The RTG images were acquired by the equipment of RTG VX100D. The location out of which the samples were taken for the porosity analysis is shown in Fig. 7. It is a structured opening connecting the flange and electric motor body.

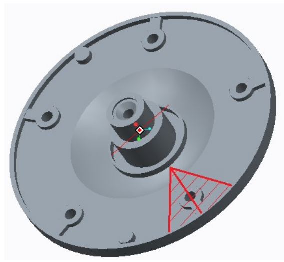


Figure 7. Location of sampling for porosity assessment

The subjects of assessment were randomly selected castings of the zero series out of which the samples were taken for production of metallographic specimens. The measured values of the castings are presented in Tab. 6.

Table 6. Porosity values of the individual samples

Sample No.	Porosity [%]	Sample No.	Porosity [%]
1.1	0.20	1.11	0.20
1.2	0.15	1.12	0.18
1.3	0.19	1.13	0.16
1.4	0.17	1.14	0.17
1.5	0.16	1.15	0.19
1.6	0.18	1.16	0.18
1.7	0.19	1.17	0.21
1.8	0.18	1.18	0.19
1.9	0.16	1.19	0.17
1.10	0.17	1.20	0.18
Mean: 0.179 **Variance:** 0.000218			

The porosity values f achieved the mean value of 0.18%. This low value proves high homogeneity of a casting which provides a precondition for good mechanical properties. By means of low porosity the higher hardness of the surface layer is reached along with lower value of permanent deformation.

4 ASSESSMENT OF RESULTS

According to the filling degree the time development of filling was elaborated. Pursuant to the measured values and their presentation in graph of dependence on time the linear dependence was observed which proves that the filling is continual and impact changes are absent as well as the mixture of the melt accompanied by air and gas locking in the melt and consequently in the body of a casting. The aforementioned meets the first requirement preconditioning the internal soundness of a casting. As the degree of filling maintained the constant value until complete solidification of a casting, i.e. for the period of time of 20.877 s, the occurrence of shrinks in the body of a casting can be thus excluded which is also proved by Fig. 5.

Percentage of solid phase in the melt represented the parameter used for checking of the continual solidification of a casting in the mold. Decrease in liquid phase in the melt after complete filling of the mold cavity demonstrated continual changes as shown in graph in Fig. 6. It could be assumed that internal stress, cracks, and cold laps shall not be formed in a casting. The RTG tests for detection of porosity proved the truth of preconditions regarding the homogeneity of a casting and the results observed in simulations.

5 CONCLUSIONS

Computer simulation represents a suitable means of optimization of die casting process offering a designer an opportunity to visualize the process, to optimize the proposed design, and to prevent the errors in projection, and to predict economic losses caused by the incorrect design of the gating system.

On the basis of the realized simulation it was proved that the initial analytical design of the gating system demonstrated errors caused by velocity and pressure losses due to extensive section areas of the ingate channels which resulted in premature cooling of the melt and consequently solidification of the ingate prior to resistance pressure. The outcome of the aforementioned was the shrinkage of a casting. Through the reverse check calculation of velocity and pressure relations the modified gating system was proposed the design of which was proved by simulation as the appropriate one. The RTG tests assessed the porosity in case of actual castings and thus confirmed the assumptions and expectations deduced in design phase of production and stemming from the theoretical bases of die casting technology.

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