GATE GEOMETRY MODEL ENHANCEMENT TO INCREASE MECHANICAL PROPERTIES OF AL-SI BASED PRESSURE DIE CASTING COMPONENTS

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ABSTRACT:

In metal casting industry, sand casting is widely used to produce a wide variety of metal components with complex geometries. In the present global scenario of recession and highly competitive environment among the foundry, cost effectiveness is a crucial role to play Foundries suffers from poor quality and productivity due to large number of process parameters, lower penetration of automations and shortage of skilled workers. In the case of the diverse height of the gate, five sets of castings were produced. The individual sets of castings were subjected to study of selected mechanical properties, i.e., of permanent deformation and surface hardness. At the same time, the individual sets of castings were subjected to metallographic examination of the eutectic structure of the Al-Si based pressure die casting. It was proved that the gate height influences the aforementioned properties of the castings and significantly affects the ratio of the eutectic phases in the volume of the casting. The conclusion describes the mutual correlation between the gate structure, the mechanical properties of the casting, and numerical flow analysis of structural composition.

Key words: *Die Casting, Surface Hardness, gate structure.*

1.0 INTRODUCTION:

Despite the metal casting process being one of the oldest processes in the fabrication of metal components, advancements in research are still required for obtaining quality products through cost effective ideas [1]. In particular, problems like quality control, low production, energy efficiency, reduction in material consumption and the impact of environmental production are frequently seen in modern casting industries. In recent days, extensive research has been done in the aspect of optimization on the casting process to identify the parameters affecting quality measures [2-3]. Accordingly, factors such as mould material, poring basin, runner and gating system have been found to have a significant effect on product quality in the casting process [4]. Hence, it is mandatory to create a database with key findings seen in published articles with respect to casting parameters on quality measures that would be useful for small scale casting industries. It is obvious that the mechanical properties of castings depend mainly on the porosity and structure of the castings. In general, a fine structure of castings provides them with better mechanical properties. The surface hardness of castings depends especially on structure [5]. The grain size in the casting depends on cooling speed or on the level of melt undercooling during contact with the mold face. It has been proved that the high pressure die casting (HPDC) process includes abrupt temperature changes on the mold surface in the course of casting cycle change. Such behavior leads to sharp heat drops on and below the mold surface [6]. When melted alloy enters the relatively cold mold cavity, the speed of solidification highly depends on the interfacial heat transfer within the mold as well as in the molten alloy and consequently influences the microstructure and mechanical properties of the final casting. In other words, correct cooling speed could lead to preferred formation of fine microstructure in the produced castings. Increase of cooling speed results in decrease of the primary size of the Si particles as well as in shortening of distance of the dendrite's second shoulder. [7] On the other hand, extreme high speed of solidification can cause premature solidification of molten metal prior to filling completion.

Die casting process:

It is a moulding process in which the molten metal is injected under high pressure and velocity into a split mould die. It is also called pressure die casting. The split mould used under this type of casting is reusable. Hot-chamber die casting, sometimes called gooseneck casting, is the more popular of the two main die casting processes. In this process, the cylinder chamber of the injection mechanism is completely immersed in the molten metal bath. A gooseneck metal feed system draws the molten metal into the die cavity. This process lends itself to higher rates of part production than with the cold-chamber process.

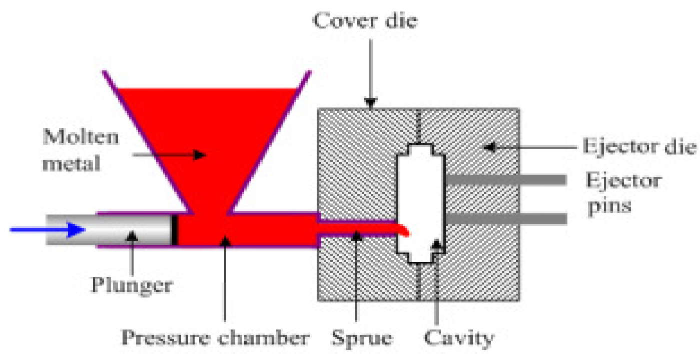


Figure 1.1. Die-casting process

2.0 LITERATURE REVIEW

Vidhate N et al. [8] states the importance of simulation in improving the quality of the casting and optimize gating/riser systems are optimized by using CAD and simulation technology with the goal ofimproving casting quality such as reducing incomplete filling area, decreasing large porosity and increasing yield.
Jaju.S.B et al. [9] analyzed and identified the gating & riser system by simulation to reduce internal shrinkage and yield% .
Suresh M. Sawant et al. [10] analysed brake disc to solve the problems like improving casting yield and casting quality. The gating system model is created using 3D CAD and simulated using casting simulation program Autocast-X flow plus software.
Boutorabi, M. A et al. [11] have discussed that the geometry and size of the gate and the ratio of the gating system has a great influence on the pattern of mold filling by experiments.

3.0 RESEARCH METHODOLOGY:

The structure of the gating system itself performs a significant function in reduction of gas retention in the melt volume and in decrease of porosity. The die casting process can be modified and the occurrence of defects can be reduced when both the gate and venting system are changed on the level of structural design of the mold according to the melt flow observed in the mold It is obvious that the porosity values and the amount of gas retained in the melt volume are influenced by the correlation of several structural nodes within the gating system beginning with correct gate design, sprues, overflow basins, and venting channels. Therefore, elimination of air retention during the first phase of designing the geometry of sprues is desired According to the aforementioned, with regards to the mechanical properties, porosity, and fineness of the crystals it is possible, to a certain extent, to influence the quality of the castings by setting the technological parameters of the die casting cycle and by a suitable structure of the gating and venting systems. In the technological preparation of casting production, however, metallurgy and melt preparation must not be omitted. The mechanical stress of castings requires A consistent, high- quality structure with maximal toughness and minimal non-homogeneity.

The chemical composition of the alloy was verified in the laboratory by means of a spectrometer Q4 TASMAN. The ambient temperature during the test reached the value of 22 ◦C and the relative air moisture content reached a level of 50%. Measuring was performed with the test samples and evaluated through the average of three sparks. The measured values of chemical composition are shown in Table

Table: 3.1 Chemical composition of alloy

Chemical Composition of the Experimental Melt of the Used Alloy [%]											
Al	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Pb	Sn	Ti
85.27	12.02	0.71	1.19	0.21	0.13	0.02	0.02	0.35	0.02	0.03	0.03

Experimental examination was carried out with a series of castings of an electric motor flange (Figure) made of alloy EN AC 47 100. The measurements were performed in the proximity of the structural hole of the casting. The location was considered to be critical with regards to further machining and mechanical stress after the casting was fixed into the electric motor setup.

Evaluation of Mechanical Properties:

The shape of the selected casting did not allow the production of testing bars designed for the statistic pull test. Therefore, the pressure test was performed (permanent deformation s) and its measuring was carried out at the critical location of the casting (flowing around the cores), installation hole according to Figure 3.1. The lowest values of permanent deformation were detected in the case of samples which were made of castings having been die cast at the gate height of 0.82 mm. On the basis of such an observation it can be assumed that the values of permanent deformation depend on the gate height due to the modulation of the flow and speed of the melt passing through the gate. Then this determines the mold cavity filling mode. The presumption is that at the gate height of 0.82 mm the melt flow reaches such speed that it determines the mold cavity filling mode in combination with turbulent and disperse flow.

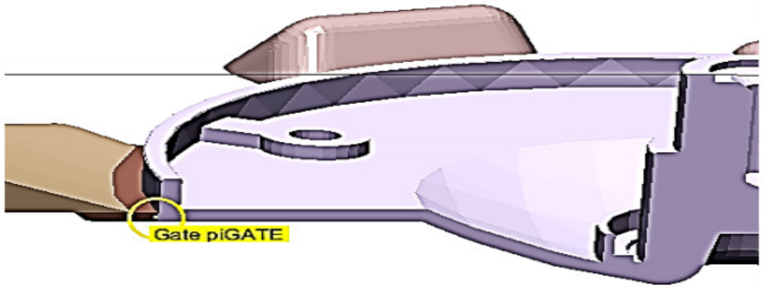


Figure 3.1 The location of the melt temperature evaluation in the gate

Assessment of the Surface Hardness:

The considerable difference between the measured surface hardness values dependent on gate height change within the framework of the performed analysis was not proved which is also clear from the obtained values. The analysis confirms the fact that the hardness of the castings depends especially on the casting structure and size of grains. The size of the crystal grains is derived from the level of undercooling of the melt when coming into contact with the mold and the speed of cooling of the melt. The determining factor of the grain size is the thermal gradient between the melt and the mold.

Characteristics of Gating System:

The gating system was designed for the casting of electric motor flange. The designed material was EN AC 47100 - AlSi12Cu (Fe) alloy of the silumin category. An analytical model of gating system was designed on the base of the methodology of gating system design. It was subsequently used for a formation of 3D model, which was designed with the use of Pro/Engineer - Creo Parametric CAD program. An optimal solution is showed in Fig. A quadruple mould was designed and the castings were connected to the gating system by the use of fan-shaped inlet slots.

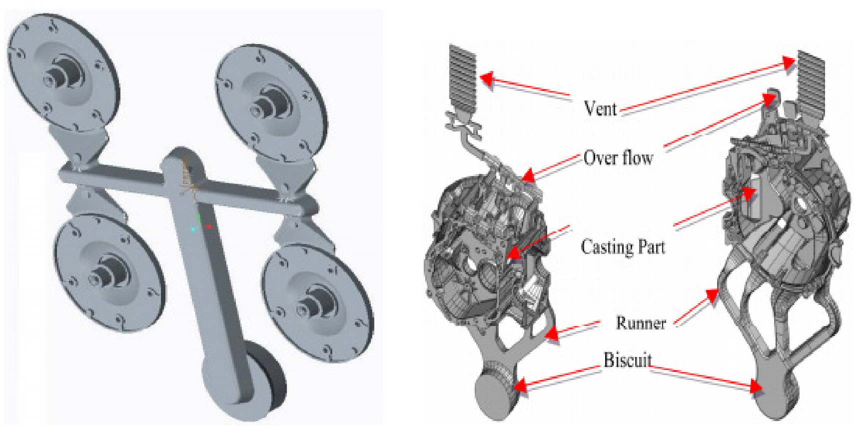


Figure: 3.2 3D model of gating system

4.0 RESULTS AND DISCUSSIONS:

Searching for the reasons of structural change it is possible to rely on the experimental research hypothesize that pressure has a similar effect in the process of crystallization and solidification of Al-Si alloys castings as their modification. According to, the effect of high pressure evinces a never increasing eutectic temperature and the point of eutectic crystallization is shifted to a higher silicon volume. The eutectic temperature is increased by about 6.3 ◦C every 100 MPa and the maximum solubility limit of silicon in aluminium is shifted by about 0.25 weight percent of silicon at the eutectic conversion. With the increasing pressure, the diameter of the primary α-phase is descending, meaning that the structure is finer and the influence of the holding pressure increases with the increasing of the casting wall thickness. In terms of the reduction of the structural parameters, only qualitative changes occur due to the pressure in the structure. Reducing the volume of the eutectic in the Al-Si alloy against the equilibrium state while increasing the silicon concentration in the eutectic and refining the structure becomes more visible the higher the pressure value. Due to the shift of the eutectic point in the equilibrium diagram of the Al-Si system, the proportion of primary α-phase with increasing pressure decreases.

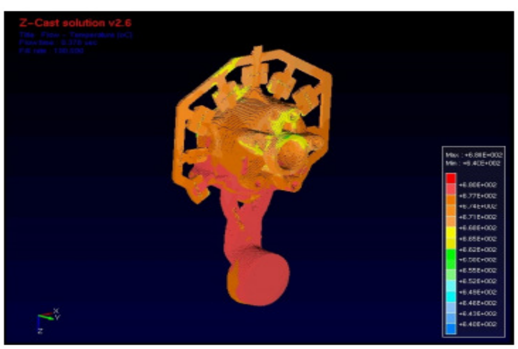
Table: 4.1 Solidification time in the area of the gate

S. No	Gate Height b, mm	Time of Solidification
1	1.25	0.354
2	1.03	0.278
3	0.92	0.264
4	0.82	0.207
5	0.75	0.205

Based on the simulations performed, the evaluation of solidification in the area of the gate shows, that decreasing the height of the gate decreases the time of solidification. A gate with lower height solidifies in a shorter interval of the time, thus the influence time of the holding pressure also shortens. The difference between the solidification times with the extreme values of the gate heights is $\Delta t = 0.149$ s. As discussed above, the proportion of primary α-phase decreases with increasing pressure.

Numerical simulation:

The numerical simulation was also done at the optimized conditions in order to predict any defects were arising in the casting. The casting simulation was done by using Z-cast v2.6 trial version. The simulation results consist of Flow analysis, Solidification analysis, and Defect analysis. The simulation results are shown below.



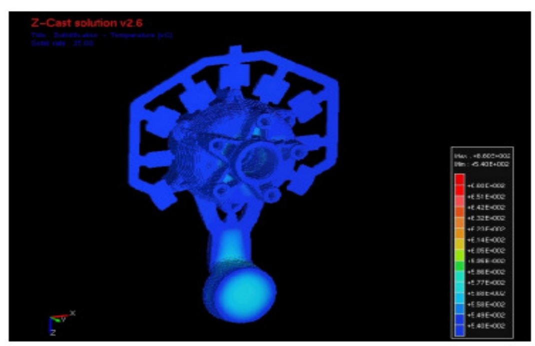
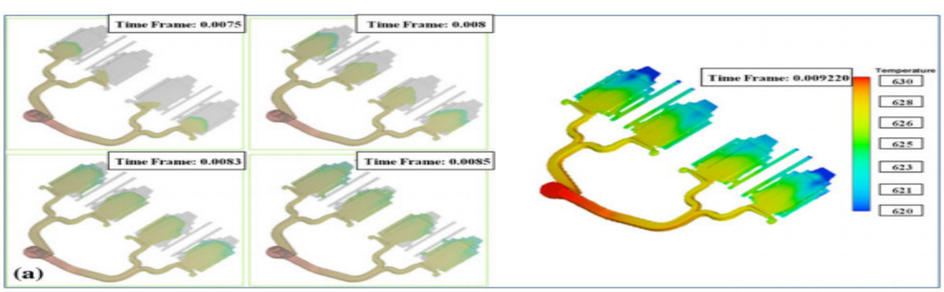


Figure: 4.2 Flow analysis **Figure: 4.3 Solidification analysis**



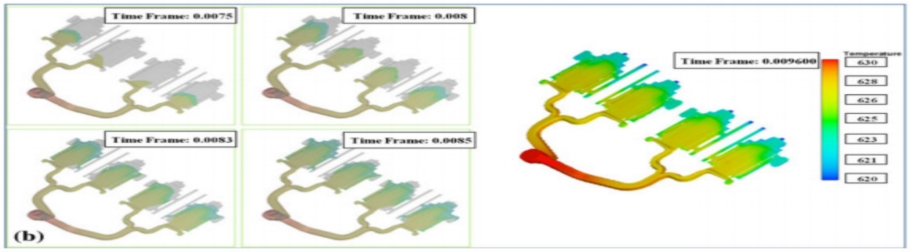


Figure: 4.4 The filling sequences of numerical simulation for: (a) original model, (b) 1st corrected model, (c) 2nd corrected model, and (d) vacuum system model

The molten fluid flows through the runners at first and fills the gates preferably. Finally, the cavity of the LCD housing was filled by molten fluid, as shown in Fig. (a). But the filling velocity in the cavity was slower than the velocity in the center because of the fast cooling and great resistance in both sides of the cavity. The filling velocity in the 2nd and 3rd cavities was 0.075 m/s faster than the velocity in the center. In this case, we predicted that the flow of unstable molten fluid will increase the amount of trapped air in the 2nd and 3rd cavities. The transition from yellow to green shows where the incoming fluid decelerates as it encounters the back-filling fluid which moves more slowly.

DISCUSSIONS:

To evaluated in the case of the test samples taken from the critical location of the casting by cutting perpendicularly in relation to the axis of the installation hole (Figure). The influence of the gate height affects the porosity values especially by shaping and directing the flow of the vmelt being forced into the shaping mold cavity and by the change of the melt speed flowing through different areas of the gate, i.e., by the change of the mold cavity filling mode The achieved results unambiguously proved that the gate height represents a significant structural dimension of the mold gating system because there occurs right in the gate itself the change of the melt flow speed and modulation of the melt flow leading to shaping the mold cavity. As a consequence, the flow determines the filling mode which influences the casting homogeneity. On the basis of the achieved results the measures for the gating system structure were adopted with regards to corrections carried out after mechanical testing of the castings.

CONCLUSIONS:

In this paper concluded that the influence of gate height on formation of the eutectic alloy structure and its influence of the properties of the castings. It was proved that the formation of the eutectic structure is influenced not only by the height of hydrostatic pressure but by the holding phase duration as well. The period of gate solidification is thus one of the determining parameters in the case of the melt to the observation of only few research focus on the study of molten metal velocity can leads to minimum the casting defects such as oxide layers, internal cracks, flow marks and porosity. The manufacture of thin wall sand casting product has been found to be limited, requiring further attention towards achieving optimum pouring temperature and riser and gate location. Achievement of this can help getting the common data base with the information on suitable pouring temperature for the corresponding wall thickness. When comparing the values of the casting porosity f and the permanent deformation s in relation to change of gate height it can be stated that with the increase of gate height the permanent deformation s increases as well. The exception to the aforementioned is represented only by the value of 0.75 mm. With regards to increasing gate height the casting porosity f tends to increase as well with deviation in the case of the value of 0.75 mm. The results point out the fact that the filling mode of the shaping mold cavity is a combination of turbulent and disperse flow

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