# Optimization of Runner Design in Pressure Die Casting

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***Abstract*— In order to produce high quality parts with high pressure die casting, computer aided simulation has been used to optimize mold designs. Finite difference (differential), finite volume and finite element methods have been used in the filling process simulation and significant progress has been made for general problems. Further work on mold design optimizations is still desired to address specific issues. In die casting, the die often has more than one cavity with multiple cavities producing the same or different parts. Multiple cavities require the application of branch runners connecting to a main runner. The design of the runner system has always been a topic for die casting, since it is important for the designer to ensure that multiple cavities start filling at the same time and have the same fill time. A key factor in the design is to adjust the cross section area of each branch runner according to the cavities' volumes; however, this may not be enough to fill the cavities simultaneously. The angle between the branch runner and the main runner has been observed to have effects on the filling pressure, filling time and residual stresses, but the observations were limited to very simple lab level die design rather than practical castings.**

***Keywords*— Runner, Gate, High pressure die casting, Fill time**

## INTRODUCTION

Die casting can be described as a process by which hydraulic energy from an injection system of a die casting machine is applied to molten metal to convey kinetic energy to the metal to achieve a fast filling of the die cavity. There are several die casting systems in use. Although they have distinctive characteristics, these die casting methods have similar mechanical design of the die, thermal control and actuation. The main two die casting processes are the hot chamber process and cold chamber process.

We are dealing with the problems in runner of Cold chamber high Pressure Die due to which there was jet marks on the product. A die in a production run has a feed system which is inaccurately designed such that flow causes erosion on the runner walls due to jet pressure formed by molten metal flowing through it. After considerably long production run a local runner area on runner wall gets wear out to form local depression which eventually causes further change in the flow direction. A solution is required with which runner shall be designed to create a molten metal flow with very less or no jetting on runner side walls to minimize wear out of runner side walls.

In order to design runner we are using P-$Q^2$ diagram [2] which is an important tool for the die casting design process. With help of diagram we get the maximum and minimum velocity and filling time which is an operational window and their effects on the production of castings. We consider a value which fits in the operational window as a factor for deciding whether the design is matching the requirement or not.

By using the simulation software we will be comparing the results of different iterations of design of die.

### *Design Methodology*

First we will be establishing the metal flow or desired filling pattern. Then we will calculate the filling time and decide the gate velocity. Establish the minimum and maximum gate depth. Match the machine and die requirements. Determine the final plunger size and slow shot velocity. Calculate the final gate and runner dimensions.

The above mentioned steps are methodology proposed by Herman for designing the gating system of castings. The design process begins with the selection of the filling pattern i.e. the desired flow of metal though the cavity. Although some guidelines and ideal filling patterns exist, the procedures are far from well understood or formalized in mathematics or a set of rules. The filling time is considered the time interval between when the molten metal starts to enter the cavity until the cavity and overflows are completely filled. Often it takes values between 0.01 and 0.06 seconds and is higher for larger castings. Also, shorter filing times provide good surface finish.

Since the molten metal does not completely fill the shot sleeve, a bigger shot sleeve means that a larger volume of air has to be exhausts through the air exhausts. The extra air increases the possibilities of gas pockets and porosity in the casting and demands a better control of the slow shot speed.

Then using the Simulation Software we can know whether the proposed design is meeting the requirements or not and then only we can proceed for production of High Pressure die Casting Die.

### *Design Considerations and Calculation*

High pressure die casting (HPDC) die gating system consists of a biscuit or a sprue, a runner, a gate, overflows and vents. There are two basic runner types: tangential and fan runner. Runner is a carefully designed part of the HPDC die. It controls the metal flow by accelerating and directing it to the right places inside the die. So while designing we need to decide which type of runner should be used.

Selection of the best place for the gate on one side of the casting and vents on the opposite side is one the important consideration while designing.

Calculation of a Maximum Die Cavity Fill Time and Selection of a Gate Velocity is another consideration which is taken. The casting should have enough space on the parting

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line for the gate and vents. The gate length is the gate area divided by the gate thickness. The gate area depends on selected die cavity fill time and gate velocity. Die cavity fill time is selected on the grounds of: Thinnest casting wall thickness; Thermal properties of the casting alloy and die materials; combined volume of the casting and overflows and Percentage solidified metal allowed during filling.

Fill Time can be calculated using formula

$$t = K\left\{\frac{T_i - T_f + SZ}{T_f - T_d}\right\}T \qquad (1)$$

t – Maximum fill time, sec
K – Empirically derived constant related to the thermal conductivity of the die steel
$T_i$ – Metal temperature at the gate, °C
$T_f$ – Liquid temperature, °C
T – Characteristic thinnest average wall thickness of the casting, mm
$T_d$ – Die surface temperature just before the shot, °C
S – Percent solids at the end of fill, %
Z – Solids unit conversion factor, °C to %, related to the width of the solidification range

Fill rate can be calculated using formulaFill rate = Volume of the metal flow through gate/ Cavity fill time (2)

Gate Area can be calculated using formula
Gate area = Fill rate/ Gate velocity (3)

Gate Length can be calculated using formula
Gate length = Gate Area/Gate thickness (4)

Runner area to be calculated using formula
Runner area = 2×gate area (5)

*Design and Analysis*

Following are the objectives to be pursued while designing

- To reduce weight of Die
- To avoid stagnation of molten metal in Runner
- To change runner to reduce machining from individual runner to common runner.
- To change biscuit cut for overflow of metal.
- To apply, computational fluid dynamic (CFD) methods to analyze a high pressure die casting (HPDC) die containing four cavities producing clutch lever.
- To analyze the influence of the runner trajectory and directional changes on the ability to smoothly fill the cavities.
- To compare different runner designs obtained by CFD simulation.

While designing we studied the existing die and did analysis which gave us better understanding of the die. The problem in the die was that the lower part of the product was filled first, after that only the upper part was filled. This caused the molten metal to solidify hence leaving unfilled spaces in the die and more parts were rejected. There were jet marks on the product due to which chances of rejection of product was more. Though the jet marks on the surface of the product could be polished and removed but if the jet marks are more, then the strength of the product was affected. The die also was affected due to which there was wear of die.

We assumed gate velocity as 45m/s which was within the operational window [2]. We tried changing the runner types like fan and tangential runner in order to understand which runner is suitable. Some of the parameters that are considered while analysis are Filling Time, solidification, ingate velocity, mold erosion, air entrapment, cold shuts etc. We compared these parameters of existing die and iterations made in the software using analytical software.

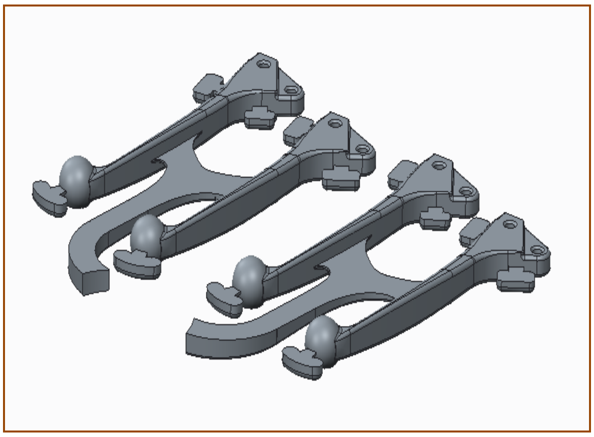

Fig. 1. Runner System of the Modified Design

From the image of the runner system we can see that main runner is joining the two clutch lever. As the main runner goes to product, if the flow is not proper it can have an adverse effect on the die and the product. That was the problem with the existing die as the metal flows through the runner to the product flow causes erosion on the runner walls due to jet pressure formed by molten metal flowing through it. After considerably long production run a local runner area on runner wall gets wear out to form local depression which eventually causes further change in the flow direction.

After designing we made analysis of the runner system in analytical software. Some of the parameters considered in analysis are shown below.

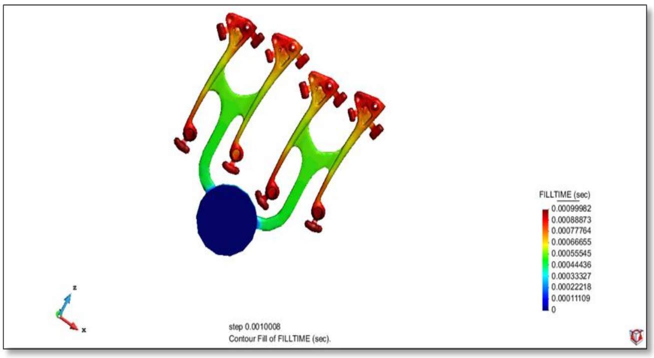


Fig. 2. Filling Time of the Modified Design

Filling time is 0.00099982 seconds as compared to fan gate runner filling time has increased but not drastically.

We made two iterations of the runner system. Before we finalized the die we did the analysis of the runner system and then incorporated the design on the die. After making design changes in the runner, the rejection rate decreased as the molten metal now completely fills the mould now. Also there is decrease in porosity as compared to the second iteration that was made. The filling time was not affected and cooling of the molten metal in the die became even due to which jet marks on the product was not visible.

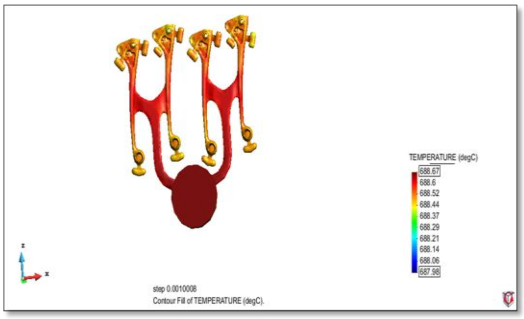

Fig. 3. Temperature of molten metal in Modified Design

We can see that red regions are also shown in the lever part. This proves that the molten metal does not solidify on its way and complete filling of mold occurs.

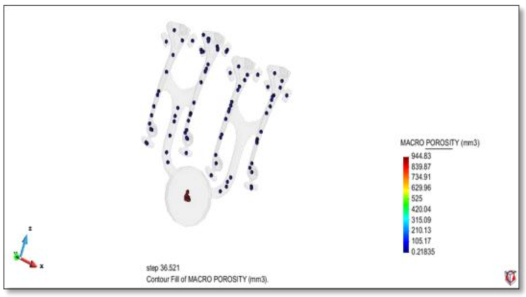

Fig. 4. Porosity in runner system of Modified Design

Compared to fan gate runner the porosity has reduced. But it does not exceed any critical limit. Also porosity in the product can be decreased if we maintain an even temperature of the die.

We made analysis of cold shuts, solidification, ingate velocity etc. from we were able to select the design which was suitable.

## CONCLUSION

In CFD analysis we found that by changing the runner from fan runner to tangential it reduced the effect of flow on the die and the product. The chances of jet marks on the die and product became less.

The rejection rate decreased as the molten metal now completely fills the mould now. Also there is decrease in porosity as compared to the first iteration that was made.

As the jet marks were reduced the post-processing of the product like polishing was not required.

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