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Runner Optimization Of Hpdc Coolant Pump Housing Component Through Flow Analysis

Sudeep I[1*], Shashank S[2], Dr.R. Nagaraja[3]
[1]*MTech, Department of tool engineering, Government Tool Room and Training center, Bengaluru*
[2]*MTech, department of tool engineering, Government Tool Room and Training center, Bengaluru*
[3]*3Principal, department of tool engineering, Government Tool Room and Training center, Bengaluru*
https://orcid.org/0009-0007-6457-1880

ABSTRACT
Die casting is an age-old process where molten metal is poured into a cavity containing the impression of the desire output to get a casted component as the final results. This process when done with the help of casting machines, involves additional process parameters such as injection pressure, clamping force, etc. An integral part of this process is also the runner design which delivers the molten metal from the barrel of the machine to the cavity of the mould. Two variations of runner design are implemented into the coolant pump housing component. The first design is a simple vertical shot runner design with sub-runners at 2 local regions. The second design is tilted shot runner design with gating points at 4 local regions. The fill time for the component is calculated based on an industrial thumb rule. Once the design and calculation is complete, the component shots are put through flow simulation and the obtained results are compared with each other and the manual calculations.
Keywords— Die Casting, Runner Design, Flow 3D Cast, HDPC, Flow Analysis

1. Introduction

Casting is essentially a process where a component is produced by allowing a molten material to take the shape of an impression in a cavity. It is a process that can be traced back all the way back 3200 B.C, where copper was popularly used in metal works due to its high ductility. As the ages go by and technology improves, the heart of the process itself remains the same. The reason casting is still a vital manufacturing method in this age of CNC's, is due to the amount of time the process saves up in machining and finishing. Complex geometries take much longer to produce purely through machining compared to casting where the casted part requires minimal machining and finishing work to reach the desired final parameters. This process is highly used in manufacturing of heavy metal components, mainly engine cases, engine heads, anchors, etc.

A typical die casting cavity consists of the impression of the component, a runner system, a gating system and overflows. The impression of the component is essentially the hollow region where the metal is accumulated and solidified for obtaining the final component. The runner system consists of a pathway channel from the sprue bush-spreader area until the gating system before the cavity. The gating system is the mediator between the runner and cavity and provides regulation to the metal flow before entering into the cavity, making it the most restrictive part of the system [1]. Overflows are simple extra pockets provided around the opposite end of the runner system to account for the material shrinkage. The runner layout must also be designed keeping in mind to abstain from including straight edges or lines as much as possible as it increases the turbulency of the flow [1]. With the implementation of larger components in the die casting process, the number of errors due to air entrapment is also a key factor to be tackled. This is negated with the help of air vents [2,3]. The factors such as number of gates and shape of gates can vary from one type of component to another, sometimes with the help of CFD simulations we can approach the right of designs that need to be followed to tackle the chances of defects once the component is

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manufactured. The experimental validation of metal flow with the help of different number of gates and runner shapes was studied [2,3,7].
The material selection and the properties play a vital role in the high pressure die casting process and it's been experimentally proven [9,10].
It was observed for this particular component in the project conventional comb gate [8] and runner type can be used. This approach however was not efficient when it was validated in the simulations. The runner plays the biggest role after the cavity itself since it is this feature that directs the flow towards various parts of the cavity for appropriate filling. This paper is about the importance of runner design and how it effects the fill time of the cavity.
The analysis is conducted for a coolant pump housing component which is made of Aluminium. The runner design is done based upon standard runner profiles and dimensions and the layout of the system was decided with general trial and error.

2. Experimental study

The general design process with respect to the design of a die casting tool has been listed in Figure 1. The component and tool design is conducted on Creo Parametric while the simulation is conducted on Flow 3D cast.

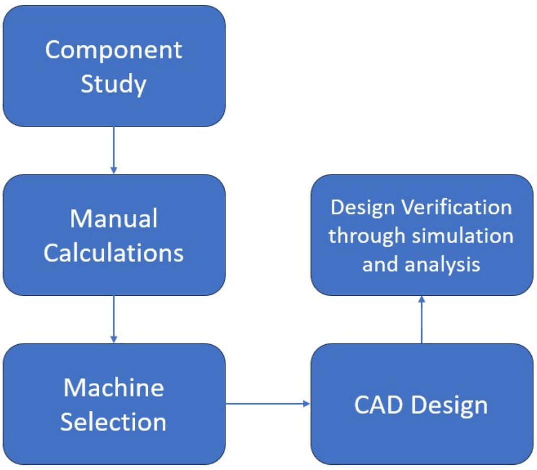

Figure 1 Design process

2.1 About Component

The component implemented in this analysis is a coolant pump housing unit as shown in Figure 2. It serves the purpose of containing the water flow within the pump unit and the inner spiral geometry helps increase the water pressure.

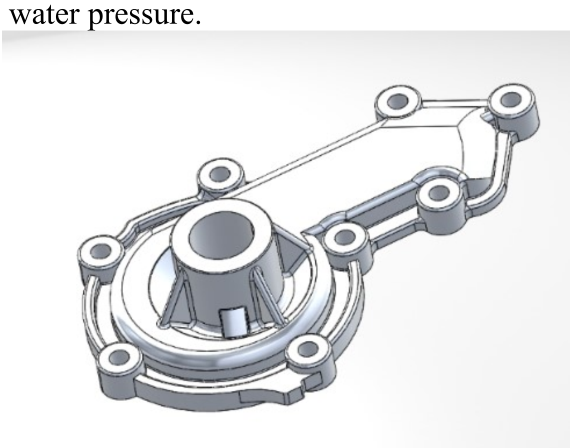

Figure 2 Coolant pump Housing

Table 1 Component Specifications

Parameter	Details
Material	Aluminium

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Density	2.7 g/cm^3
Shrinkage	0.6%
Draft Angle	1^o
Max Dimensions (l x b x d)	217 x 130 x 43 mm
Volume	152089 mm^3
Wall Thickness	4mm

2.2 Manual Calculations

A few of the needed manual calculations have been listed as follows:

- Weight of the component = 430g
- Weight of single component = component weight + 30% of component weight

Weight of single component = 430 + (0.3 x 430) = 560 g

- Volume of metal through gate

Vm = Vc + Vo

Vc = 152 cm3

Vo = 10% of Vc = 15.2 cm^3

Vm = 152 + 15.2 = 167.2 cm^3

- $Fill\ time = \frac{(wall\ thickness)}{0.5} \times 7 = \frac{4}{0.5} \times 7 = \mathbf{56\ milliseconds}$
- Required minimum runner width x depth = 22x11 mm

2.3 Runner Layout

The runner cross-section chosen is the half-round runner due to its simplicity in manufacturing and it is also the ideal choice when it comes to irregular runner layouts. The layouts chosen for this analysis includes a vertical layout and a slanted layout. The gating for both the layouts include the usage of fan/edge/rectangular edge gating. This is used for better material distribution and lesser obstruction to the metal flow. The 2 runner-gating layouts have been explained as follows.

Vertical Shot runner layout with 2 gate regions

This runner layout is chosen mainly due to the simplicity of the design. The gating regions are fixed only to 2 locations since the runner layout being vertical, anymore gating regions in the sides would not help majorly in flow distribution due to gravity. The shot has been shown in Figure 3.

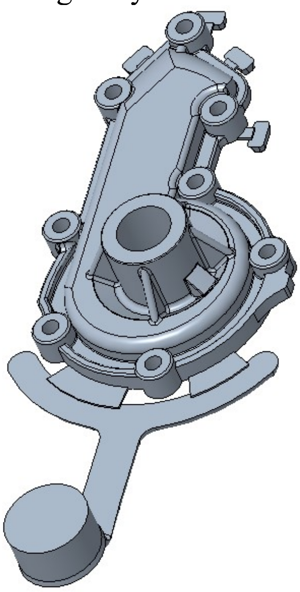

Figure 3 Vertical Shot

Slanted Shot runner layout with 4 gate regions

This runner layout is designed as an improvement to the vertical shot layout. The titled nature of the shot improves the flowability of the metal as the effect of gravity is reduced. Since the shot is slanted, a lot more area is viable for implementing a larger runner system with 4 gating locations. The show has been shown in Figure 4.

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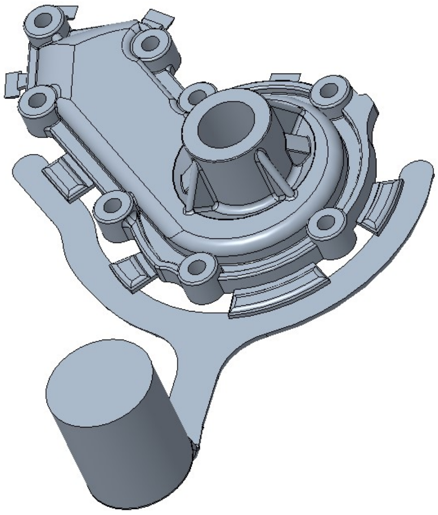

Figure 4 Slanted Shot

Another additional feature is this particular runner design is the initial runner cross section as show in Figure 5. The purpose of this feature is to provide a nozzle effect and increase the flow velocity before the gating area.

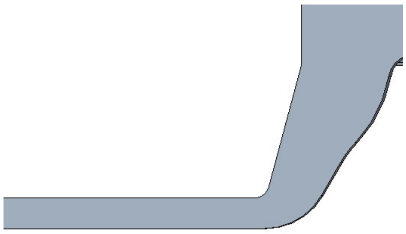

Figure 5 Initial Runner Cross-Section

2.4 Flow Simulation

The 2 final shots are used for the flow analysis process. The software being used here is Flow 3D Cast. The input parameters for the process has been listed in Table 2. The input parameters are based on material properties and general standards.

Table 2 Input Parameters

Parameter	Value
Alloy Material	Aluminum
Element	Triangle
Alloy Volume Element size	5mm
Die Volume Element size	10mm
Alloy Temperature	650^0 C
Die Temperature	80^0 C
Mass Flow Rate	1.6521 kg/sec

3. Results and Discussion

After the simulation is run, the results are to be analysed and studied. The analysis will mainly be focused on the fill time of the shot, while other results are also obtainable through the simulation such as temperature gradient, velocity of flow, air traps, venting requirements, etc.

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3.1 Fill Time

Fill time indicates the time within which the entire cavity including the runner system is completed filled with the molten metal. Fill times are crucial since fill times directly dictate the cycle time of the machine which indicates the productivity of the machine itself. Faster fill time leads to lower cycle times, meaning more components can be produced within a given space of time. Fill time is highly dependent on the runner-gating layout and the injection pressure.

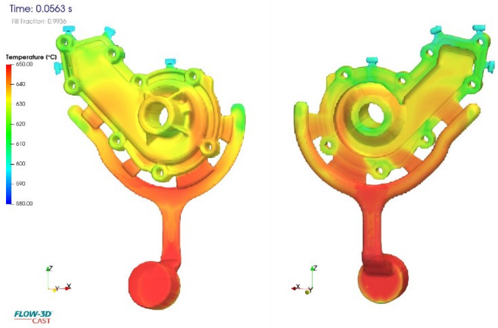

Figure 6 Slanted Shot Temperature Gradient with Fill Time

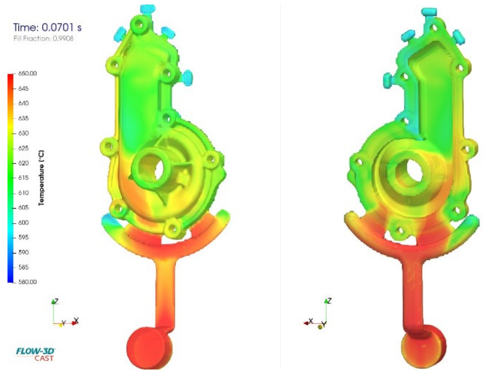

Figure 7 Straight Shot Temperature Gradient with Fill Time

As indicated in Figure 5 and Figure 6, the fill time for the slanted profile is lower compared to the fill time of the vertical shot. There also a difference in the fill fraction between both the shots. The slanted shot has the better fill fraction compared to the latter.

3.1 Velocity Gradient and Flow Profile

In a cavity for a relatively large component, material flow is key in accurate filling of the component. Geometries of higher wall thickness or intricate geometry is regarded as a higher priority in terms of material allotment as these taken longer to fill, which means the slower they get the material the higher the chances of those regions not being filled resulting in a short shot.

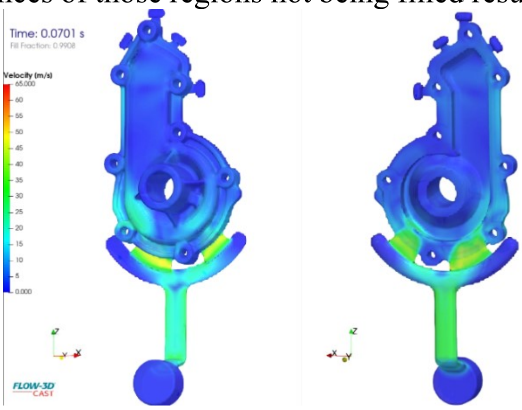

Figure 8 Straight Shot Velocity Gradient

As shown in Figure 7, the vertical shot has the highest concentration of velocity at the beginning runner areas and the 2 gating regions. This flow profile also poor since even though the upper region

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gets the initial flow, the drastic reduction of velocity at the gating region forces the melt to reach the upper region slower than expected.

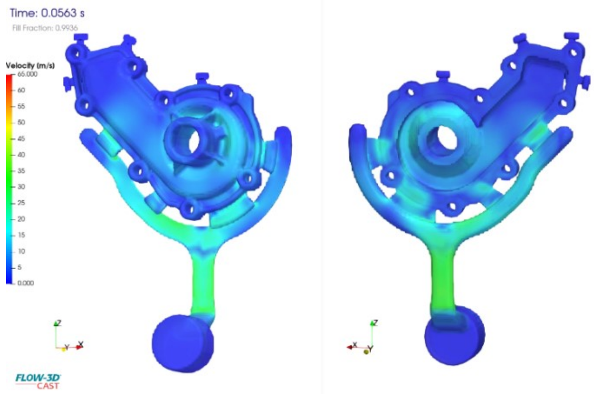

Figure 9 Slanted Shot Velocity Gradient

Figure 8 shows the velocity gradient for the slanted shot. From the gradient, we can see the runner acts like a nozzle and forces the metal to a higher velocity before the gate itself. The gate only serves the purpose of distributing the material evenly. From the flow analysis, it is seen that the flow and fill is even throughout the component while also keeping the complex geometries (upper regions and central bore) at a higher priority during the fill.

Conclusion

Upon studying the results obtained from the simulation process, we can reach a conclusion claiming the slanted shot to be the better approach in terms of runner-gating layout design for this particular component. The slanted shot has a combination of better fill time and better filling profile of the 2 layouts. The material flow is better in the slanted shot as the material filling is directed towards the thicker and harder to reach areas as the first priority. A few other conclusions have also been listed as follows:

- A valid runner design is one where the runner-gating system only aids in proper cavity filling and in no way inhibits the flow.
- Gravity plays a major role in the filling process and the design of the runner system has to take even that into account.
- The slanted shot is ideal for the filling process since the runner design increases the flow velocity at the right places and is setup in such a way that the major complex filling regions are tackled first while also keeping the flow rate consistent and even throughout the cavity.

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