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Die Casting Simulation for a Filter Cap using Z-Cast

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Abstract

In this article we report an attempt to optimize using Z-Cast, the parameters for hot chamber die casting process such as velocity of the melt, temperature of the die and casting temperature to designthe gating system for filter cap using the material ADC 12 based on casting theory. Maintaining all other geometric parameters constant, we have tried to understand the design parameters for two values 1.5mm and 2mm of gate thickness. We have found that the design with 1.5mm gate thickness gives better results in terms of shrinkage compared to that with 2mm thick gate.

Keywords: *Gating Design, Niyama Criterion, Overflows, Post Processing Tessellated Model*

1.0 Introduction

Die casting is a precise and high volume production process in which a molten metal is forced into a die assisted by a coolant that is flowing through the die sections. After solidification, the part is ejected by relaxing the die clamping and it is subjected to additional cooling and finishing, machining[1]. Simulation of a casting enables one to try out different combinations of process parameters to improve the quality and yield of a casting.

Flow simulation gives location, pressure and velocity of melt during filling and solidification simulation gives spatial temperature and cooling rate. Further, simulation gives phase distribution, microstructure, cooling stresses and casting distortion. The defects related to solidification will be predicted precisely by software and is followed by flow-related defects such as cold shut, misrun and sand inclusion[2]. Blow hole and gas porosity are difficult to predict and are highly dependent on shop-floor conditions that cannot be captured in simulation. Cooling-related defects: hot-tear, distortion and hard-spots can be predicted by a few simulation software but with a lower level of accuracy.

In order to obtain defect free casting, the runner and gating system has to be designed precisely[3]. Most of the times, defect in the casting occurs due to improper runner and gating design. Before carrying out the simulation process, the gating system, runners and the overflows for the model i.e. filter cap is designed based on the calculations.

2.0 Materials and Methods

2.1 Materials

The material used for simulation of the filter cap was ADC 12. The ASTM equivalent of ADC 12 is 384 which

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has a density range of 2.6 to 2.8g/cc. It is an Aluminium alloy with the following composition (Table 1):

Table 1. Material composition of ADC 12

Silicon	9.6 - 12%
Copper	0.5 - 3.5%
Magnesium	0.3%
Zinc	1%
Manganese	0.5%
Iron	0.9%
Nickel	0.5%
Tin	0.2%

2.2 Process Parameters

The dimensions of runner and gate were decided based on the following parameters:

Type of the process- Aluminium cast parts were produced using Cold chamber die casting process[4].

Initial temperature of the melt (T_i) - The initial temperature of the alloy used in the simulation is 700°C.

Fluid temperature (T_f) - The final temperature of the solidified material is 580°C.

Die temperature (T_d) - For the gating and runner design, the die temperature used for the current study is 200°C and for the simulation study, the die temperature is varied between 180-220°C.

Velocity of the melt is 40m/s.

Fill time (t) - The time required to inject the molten metal to the mold until all the cavities are filled is the fill time.

2.3 Calculation of t:

Fill time (t) = $k (T_i - T_f + S*Z) H/ (T_f - T_d)$

T_f = 580°C, T_I = 700°C, T_d = 200°C, K = 0.0346 s/mm, S = 25%, Z = 4.8ºC

H(average thickness of the component) = 1.5 mm

Fill time t = 0.0346(700-580+0.25*4.8)1.5/(580-200) = 0.0305 s.

2.4 Calculation of A_{gate}, T_g, L_g and A_{runner}

These are designed using NX 9.0 software. The type of gate used is fan gate and the runner shape is trapezoidal.

I. Area of the gate, (A_{gate}) = (V_{part} +($V_{overflows}$)/(v_{gate}*t).
Volume of the component, V_{part} = 62889.1588mm^3,
Volume of the overflows, $V_{overflows}$ = 2425.5032mm^3,
Velocity at the gate, Vgate = 40m/s and fill time, t = 0.0305s.
Therefore, A_{gate} = 53.53mm^2.

II. Gate thickness (T_g) is calculated according to the formula,
$v_g * T_g * \rho \geq J$.
Where, v_g is velocity at the gate, T_g is thickness of the gate and ρ is density of the alloy.
J = 998000 (a constant for aluminum, magnesium and zinc alloys).
$40 * T_g * 251 * 10^3 \geq 998000 => T_g \geq 0.75$mm
The recommended T_g for aluminium alloys ranges between 0.8 mm and 3 mm.

III. Length of the gate(L_g) is calculated using the formula,
$L_g = A_{gate}/T_g$ = 53.53/2 = 27 mm.

IV. A_{runner} should be twice the A_g.
$A_{runner} = 2*A_{gate}$ = 108mm^2.

2.5 Overflows

They are cavities and passages in the die which act as vents for air to escape and traps for excess metal flow[5]. Overflows reduce/prevent porosity in the die casting and

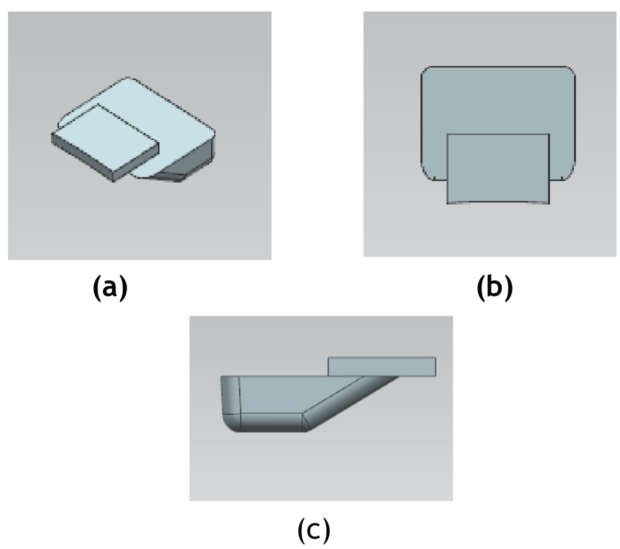


Figure 1. **(a):** Isometric view of overflows.**(b):** Top view of overflows. **(c):** Side view of overflows. Assembly of the Components

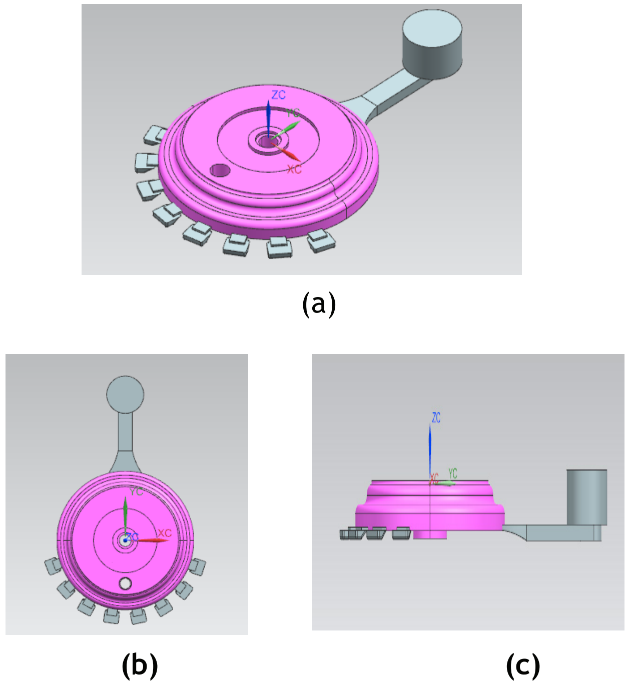


Figure 2. **(a):**Top view of assembly.**(b):** Isometric view of assembly. **(c):** Front view of assembly.

promote complete metal fill into the far sections of the cavity (Figure 1(a)-1(c)).

2.6 Assembly of the Components

The components with the gates and overflows are assembled together[6]. Constraints are given to the mating components so that the gates and overflows are aligned properly with respect to the filter cap model. The components are assembled using the NX 9.0 software for the current work (Figure 2(a)-2(c)).

2.7 Conversion to STL files

After the assembly of individual components, it is exported as a STL file format which is universally accepted across various design software. The gate, component and the overflows are exported as separate files by selecting each component.

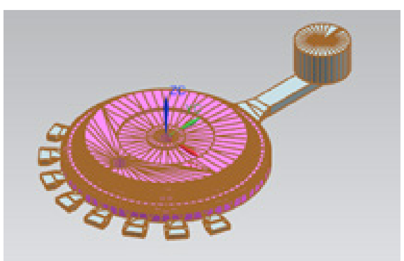


Figure 3. Tessellated model.

3.0 Simulation

3.1 Pre-processing Stage

The assembled model is imported to a Z-Cast software. It is imported as a separate STL files.

After importing the model, the mold is generated. The Z-Cast software has a provision to automatically generate the mold. Generally, the mold is generated by making the positive Z-axis co-ordinate zero. Mold will not be generated above the positive Z-axis. The metal is poured or injected in the negative Z-axis direction (Figure 4).

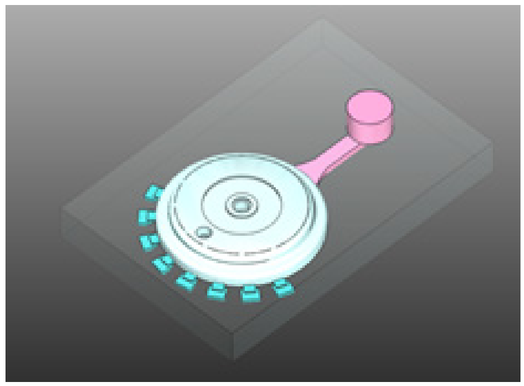


Figure 4. Component after mold generation.

Once the mold is generated, the component assembly is meshed. This is an important step as the results depend

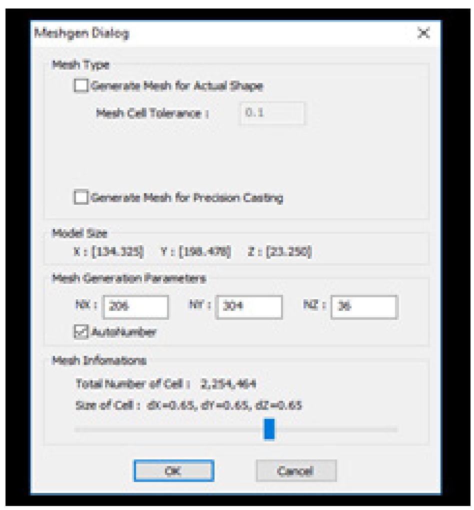


Figure 5. Dialog box to create mesh.

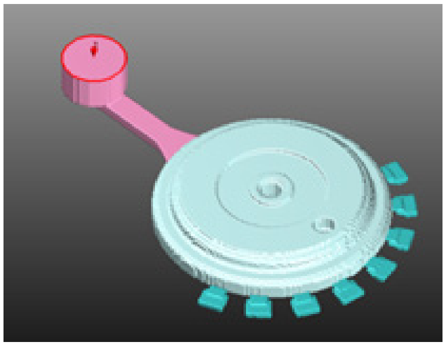


Figure 6. Ingate setting.

on the accuracy of the mesh[8]. The mesh is checked to see whether there are any gaps between the mating components. Z-Cast does not require to create a mesh manually. The size of the mesh for the current work is taken as 0.65 mm in x, y and z directions.

Material properties for the mold, component, overflows and the gate are assigned. The material for the mold is selected as SKD 6 andADC 12 is selected for the gate, overflows and the gate. The pouring temperature of the metal is varied from 680°C to 720°C and the die temperature is varied between 180°C to 200°C for a number of trials.

The ingate velocity is taken to be 40 m/s.

The ingate area, the top part of the circular section through which the material is forced through the cavity is selected.

3.2 Solver Stage

- The software provides us with two types of simulation-flow simulation and solidification simulation. The flow simulation gives the idea of a flow of a molten material within the cavity as well as the gates. It also gives the temperature of a material at a particular time of flow and also the velocity of the melt. The solidification simulation gives the pattern of solidification and also the shrinkages after solidification. For the current study only solidification simulation is considered to check for the defects.
- Parameters that are input to the solidification simulation are volumetric shrinkage equal to 0.5% and the temperature equal to 560°C.
- The number of steps to be saved is taken as 50. For each 2% solidification, the corresponding time taken to solidify is saved.

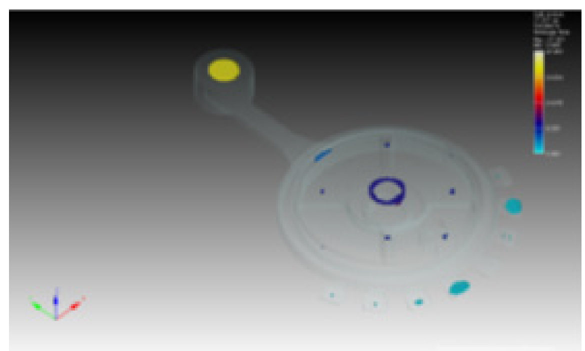
4.0 Results and Discussion

The results are analyzed for the simulations that are carried out for a gating system for two different thicknesses of the gate. 16 trials are conducted for each thickness. The Ingate velocity was maintained at 40ms^{-1}. Melt temperature was varied from 680°C to 710°C in steps of 10°C and for each case the die temperature was varied from 180°C to 210°C in steps of 10°C.

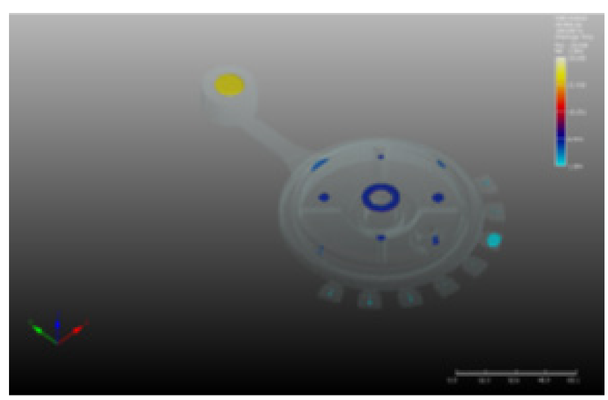
4.1 Gate of Thickness 2mm

4.1.1 Shrinkage

The shrinkage patterns were similar for all the trials. There were no significant change in the shrinkage with temperature of the melt and also there was no noticeable change in the shrinkage of a component with the die temperature. The shrinkage was observed mainly near the central hole. It is the outer sunk or pull down type of shrinkage where the depression on the surface of



(a)



(b)

Figure 7. **(a):** Shrinkage for die temp-200°C and melt temp-700°C. **(b):** Shrinkage for die temp-210°C and melt temp-710°C.

the component is formed. This is mainly due to the flow of molten metal within the cavity. The shrunk portion i.e. the region near the central hole is the last portion to solidify. The other type of defect formed is porosity, which is formed on the top surface of the casting.

Out of the 16 trials conducted, the shrinkage was the least when the melt temperature was 700ºC and the die temperature was 200ºC and,was maximum when the melt temperature was 710ºC and die temperature is 210ºC. The shrinkage was above the permissible limit in both these cases. So the gating system as well as the locations of the overflows have to bechanged. For rest of the trials the shrinkage porosity slightly varied from one another.

4.1.2 Solidification time

The Table 2 indicates the solidification time observed for each trial.

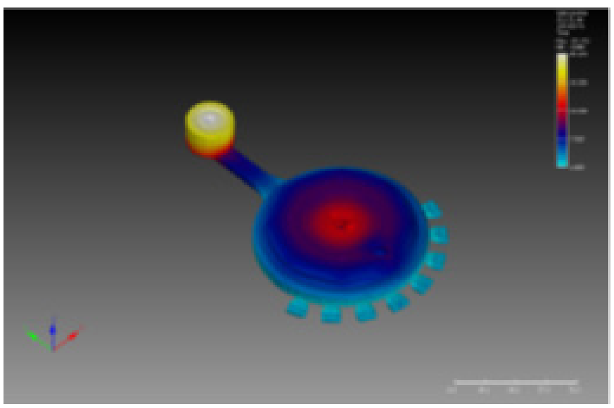


Figure 8. Solidification time plot.

From the table it can be inferred that with increase in temperature of the melt the solidification time increases and it is the case for all the die temperatures.

From the Figure 8 it is evident that the walls are the first region to solidify and the molten metal flows inwards towards the hole. The central region is the last region to solidify. The color coded patterns in the figure shows the different time intervals for the solidification to complete.

4.1.3 Niyama Shrinkage

Niyama Criteria[7] is used to predict the micro porosities in the casting. When the Niyama value decreases below a critical value, small amounts of micro-shrinkage begin to form. The critical range of values for aluminium alloys are 0 and 0.3. The value 0 indicates the poor solidification and the probability of micro shrinkage is more. The below figure is the simulation result of the component for die temperature 200ºC and melt temperature 700ºC. The micro shrinkages are in acceptable limit (Figure 9).

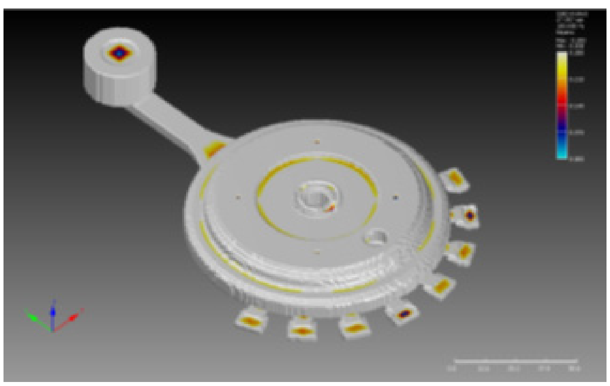


Figure 9. Niyamashrinkage plot.

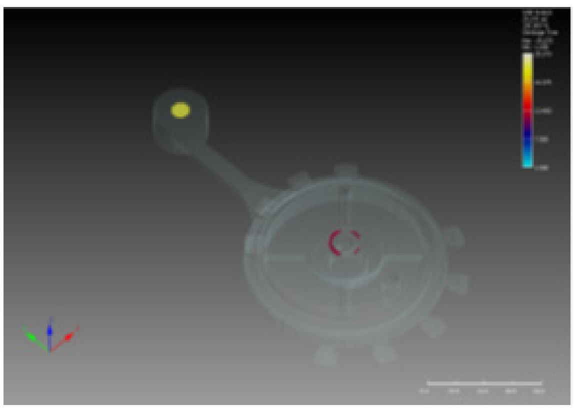
Table 2. Solidification time output

Temperature of the melt	680(ºC)	690(ºC)	700(ºC)	710(ºC)
Die Temperature (ºC)	Solidification time (s)	Solidification time (s)	Solidification time (s)	Solidification time (s)
180	25.170	25.614	26.100	26.336
190	25.872	26.248	26.618	26.983
200	26.543	26.916	27.357	27.667
210	27.323	27.743	28.067	28.608

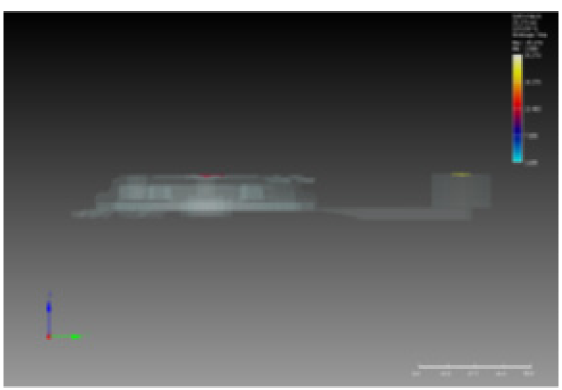
4.2 Gate of Thickness 1.5mm

4.2.1 Shrinkage

Shrinkage was considerably reduced when the thickness at the gate was reduced to 1.5 mm. Since the gating area was unchanged, the length of the gate was increased. The length of the gate for the thickness of 1.5 mm was 35 mm. Overflows were provided both at the top and bottom. There was no porosity type of shrinkage defect but there was outer sunk or pull down type of shrinkage defect on the top surface near the hole which was similar to the previous case. But there was a considerable reduction in the defect. The best results were obtained when the die temperature was 180ºC and the melt temperature was 210ºC. There was a minor shrinkage for these temperatures. The figure given below shows the shrinkage pattern when the die temperature was at 180ºC and melt temperature at 710º.



(a)



(b)

Figure 10. **(a):** Shrinkage observed for Die temp 180ºC and melt temp 210ºC (Isometric view). **(b):** Shrinkage observed for Die temp 180ºC and melt temp 210ºC (Front view).

4.2.2 Solidification time

Table 3. Solidification time output for gate of thickness 1.5 mm

Temperature of the melt	680 (ºC)	710 (ºC)
Die Temperature (ºC)	Solidification time (s)	Solidification time (s)
180	24.102	25.100
190	24.692	25.760
200	25.324	26.415
210	25.985	27.106

The solidification time has been reduced when the thickness at the gate is reduced from 2.00 mm to 1.5 mm (Table 3).

4.2.3 Niyama Shrinkage

The Figure 11 shows the niyama plot for the simulation parameters of die temperature 180ºC and melt temperature 210ºC. The value 0 indicates the probability of microporosity is more and higher value indicates the probability of microporosity is less. It can be inferred that the probability of microporosity is more but it is under acceptable limit.

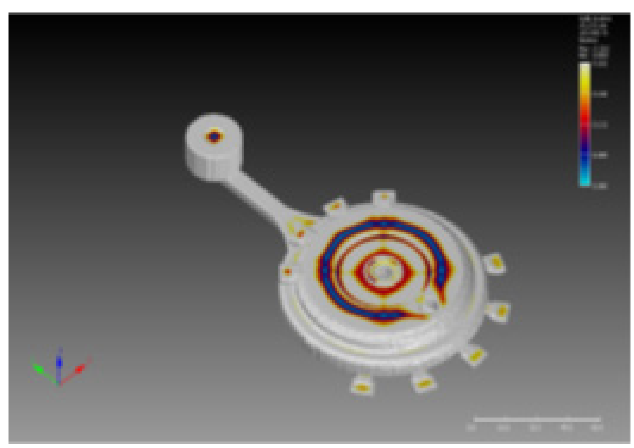


Figure 11. Niyama plot.

5.0 Conclusion

When the thickness at the gate is 2mm and the length is 27mm. The porosity and pull type of shrinkage is observed on the top surface of the component. The variation in the parameters had no effect in the reduction of the defects. Probability of micro-shrinkage was less. Considering the porosity and outer sunk effect the model is not practically acceptable and has to be improved. With the thickness at the gate and the length being 1.5 mm and 36 mm respectively. The porosity type of shrinkage effect has vanished but there was pull type of shrinkage effect. The pull type of shrinkage effect has been reduced considerably compared to the first case. The probability of porosity was more compared to the first case. But the micro shrinkage was under acceptable limit under Niyama criteria. It is not possible to simulate the component of zero defect. Considering practical circumstances, the defects caused are under acceptable limit.

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