An Estimation of Solidification Time by Varying Pouring Temperature in Investment Casting Process.

Yogesh A. Joshi¹ H.D. Patel¹
¹Mechanical Engg. Department
²Professor Mechanical Engg. Department
¹,² Government Engg. College, Dahod

Abstract--- Solidification is a very crucial factor for any casting process. Generally directional solidification will help to achieve a good quality casting product. It has been observed that casting defects like porosity, misrun, slag, etc. can be minimize by providing directional solidification. Different rate of pouring temperature will also affect the solidification rate of casting and so quality of casting.

I. INTRODUCTION

It is obvious that casting has a wide range of application but here we have to consider that there is so many draw back in it like skilled labour requirement, higher material loss, higher rejection rate. Machining required for finishing, etceteras. To accommodate such draw back so many improvisation has been made in casting process and because of that die casting, shell casting, centrifugal casting, investment casting, etceteras are introduced to the world.

Foundry industry is well aware of the fact that knowing solidification sequence is very important to design risers and their connections. Furthermore, knowing the solidification sequence and contours enables the foundry engineer to improve the manufacurability by modifying the original casting designs which are created by the design engineers who are often not familiar with the solidification and how the design parameters affect the solidification patterns.

It is also observed that results from simulation were in excellent agreement with the result from calculations. This confirmed that casting simulation technology might substitute the casting laboratory in engineering education.

Among of all casting processes here we selected investment casting process to estimate the solidification time by varying level of pouring temperature. A valve body is used for this study in which WCB (wrote cast iron with grade B) material is used. 3D CAD model is generated for the experiment and it is simulated in Pro-cast at three different temperatures. First theoretical solidification time of this model is finding out by using chvorinov’s rule.

STUDY:

A. The Theoretical Aspects of the Study

The solidification time is a function of the volume(V) of a casting and its surface area (A), which is defined by Chvorinov’s rule. In simple terms the rule establishes that under otherwise identical conditions, the casting with large surface area and small volume will cool more rapidly than a casting with small surface area and a large volume. The relationship can be written as:

\[ t = B \left( \frac{V}{A} \right)^n \]

Where, \( t \) is the solidification time, \( V \) is the volume of the casting, \( A \) is the surface area of the casting that contacts the mold, \( n \) is a constant, and \( B \) is the mold constant. The mold constant \( B \) depends on the properties of the metal, such as density, heat capacity, heat of fusion and superheat, and the mold, such as initial temperature, density, thermal conductivity, heat capacity and wall thickness. The metric units of the mold constant \( B \) is \( \text{min/cm}^2 \). According to Askeland, the constant \( n \) is usually 2, however Degarmo claims it is between 1.5 and 2. The mold constant of Chvorinov’s rule, \( B \), can be calculated using the following formula:

\[ B = \left[ \frac{\rho_m L}{(T_m - T_o)} \right]^2 \left[ \frac{\pi}{4kpc} \right] \left[ 1 + \left( \frac{c_m \Delta T_o}{L} \right)^2 \right] \]

Where

\[ T_m = \text{melting temperature of the liquid} = 1520^\circ\text{C} \]
\[ T_o = \text{initial temperature of the mold} = 900^\circ\text{C} \]
\[ \Delta T_o = T_{\text{pour}} - T_m = \text{superheat} = 30^\circ\text{C} \]
\[ L = \text{latent heat of fusion} = 180 \text{KJ.Kg}^{-1} \]
\[ k = \text{thermal conductivity of the metal} = 6970 \text{W.m}^{-1}.\text{K}^{-1} \]
\[ \rho = \text{density of the mold} = 2200 \text{Kg.m}^{-1} \]
\[ c = \text{specific heat of the mold} = 1130 \text{J.Kg}^{-1}.\text{K}^{-1} \]
\[ \rho_m = \text{density of the metal} = 7100 \text{Kg.m}^{-1} \]
\[ c_m = \text{specific heat of the metal} = 450 \text{J.Kg}^{-1}.\text{K}^{-1} \]
\[ \frac{V}{A} = \text{volume to surface ratio} = 2.45 \text{mm} \]

In this work mathematical solidification time of whole assembly is 17 minutes computed.

II. EXPERIMENT AND RESULT

A. Input Data

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal pouring temperature</td>
<td>1550, 1600, 1650°C</td>
</tr>
<tr>
<td>Mould temperature</td>
<td>850°C</td>
</tr>
<tr>
<td>Convection metal to mould</td>
<td>600 W/m²K</td>
</tr>
<tr>
<td>Convection mould to atm</td>
<td>43 W/m²K</td>
</tr>
<tr>
<td>Cooling type</td>
<td>Air cooling</td>
</tr>
</tbody>
</table>

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POURING TEMPATURE | INITIAL SOLIDIFY | HALF SOLIDIFY | FULL SOLIDIFY
--- | --- | --- | ---
1550°C | ![Image](image1.png) | ![Image](image2.png) | ![Image](image3.png) | 988.37 second
1600°C | ![Image](image4.png) | ![Image](image5.png) | ![Image](image6.png) | 1015.48 second
1650°C | ![Image](image7.png) | ![Image](image8.png) | ![Image](image9.png) | 1010.84 second

### III. CONCLUSION

Here we can see that by varying the pouring temperature we get different rate of solidification time. It is also seems that by increasing pouring temperature there no significance change in solidification time. Melting temperature of WCB is 1530°C, so when we poured metal at 1550°C it was solidified in 988.37 second but the pattern of solidification is not satisfactory as we can see so many colours in sprue and it may be causes porosity. While we poured metal at 1600°C and 1650°C the results are much similar it means excessive temperature doesn’t make any different in quality as we can see the very similar solidification pattern in both case and they’re very negligible difference in solidification time.

### REFERENCES
