Solidification Analysis of Valve in Investment Casting and its Optimization using Simulation

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Abstract-Valve is most common part for every Fluid handling industry. Production of cast Valve is critical because, in today's competitive world customer wants fast and accurate Component. Computer simulation tools are used to reduce a time for development of a component. Simulation software is mainly used to visualize a complete process of solidification, which is not possible in real casting process. Defects such as shrinkage porosity, gas porosity, unfilled mould, cold shut etc. can also graphically observe with simulation. Initially CAD model of impeller has been prepared, then export for simulation. Many researchers reported that about 90% of the defects in castings are due to wrong design of gating system and only 10% due to manufacturing problems. Casting simulation process can able to solve these problems. To study the solidification behavior and detection of hot spots in castings with the help of casting simulation software. The simulated results also compared with the experimental works.

Keywords: Investment Casting, Simulation, Shrinkage defect, Optimization.

I. INTRODUCTION

Casting is the most commonly used manufacturing process. Because the development of computer technology, we can check the physical phenomenon that are involved for the defect. Modelling approach based on the description of physical processes has become a more real, practical and easy option. Shrinkage related defects result from the interplay of phenomena such as fluid flow, heat transfer with solidification, feeding flow and its free surfaces, deformation of the solidified layers and so on.

The rate of solidification governs the microstructure largely, which in turn controls the mechanical properties like strength, hardness, machinability, etc. The location, size and shape of riser in a casting depend on the geometry of the casting, mould design and thermal properties of metal, old and other process parameters. Wrong designed riser results either defective casting with shrinkage cavity or lower yield, as directional solidification has not achieved.

Hence, proper design of risering system and good control over the process parameters are necessary for quality castings. From realistic considerations, the experimental routes are always better for design and development of mould and for arriving at the optimum process parameters. However, it is costly, time consuming, and may be impossible in some cases. Therefore, casting simulation process is a convenient way of proper design of risering system and analyzing the effect of various parameters. There are number of casting simulation software are developed and are used in foundry worldwide. The application of casting simulation software are also increasing day to day in Indian foundry as it essentially replaces or minimizes the shop floor trials to achieve the desired internal quality at the highest possible time.

Despite the extensive literature on simulation of Investment casting, surprisingly few studies have been made of the simulation process or in the wider context has there been much discussion of different methods of simulation as a whole.

1	Material Grade	ACI—A494 ASTM--- CU5MCUC
2	Total pouring time	13 Seconds
3	Pouring Temperature	1620 C
4	Yield	40.83%
5	Solidification time	4-5 minutes
6	Density	8.14 kg/m^3
7	Casting weight	37.506 Kegs.
8	Chemistry of component	C- 0.05 % Ni-38 to 44 %
		Si- 1%
		Mn-1%,
		Cu-1.5 to 3.5%
		S-0.03%,
		P-0.03%
		Cr-19.5-23.5% Nb-0.6 to 1.2%

Table. 1: Information about Process [9]

II. PRIMARY DESIGN

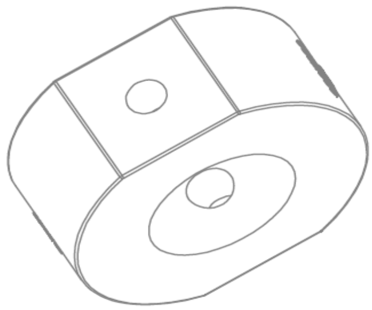

Fig. 1: Casting Part no. [9]

Casting Component is three piece ball valve and used for the Fluid handling system and used investment casting manufacturing process for better surface, Uniform internal stress and no need to machining for this heavy component.

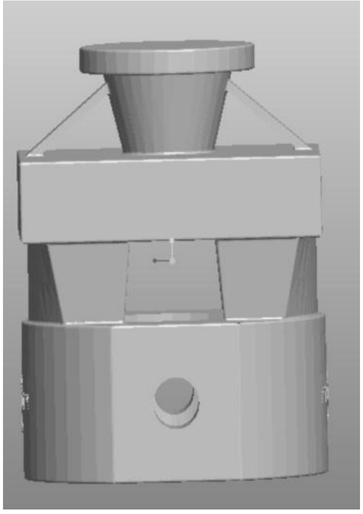

Fig. 2: Primary Gating System

Gating system is been designed based on the experience first, in that there are two gates are there and Runner is there shown in Fig. 2. Two gates are designed at the corner of the component because there are maximum chances of Shrinkage and porosity there. After creating 3D model of that part and gating system .STL file has been uploaded to the Simulation and Methoding software for analysis.

There are different results we can get in to the simulation like Temperature graph, Hotspots locations and intensity, and Temperature gradient vector maps.

A. *Simulation of Primary Design*

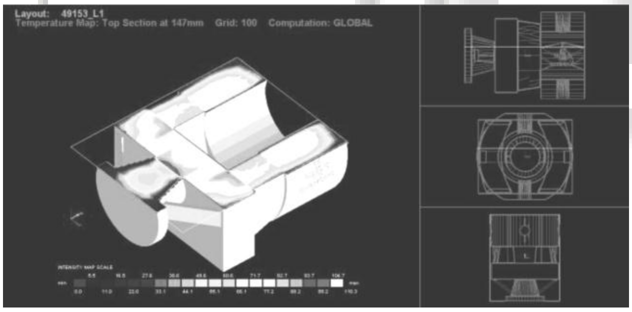

Fig. 3: Temperature Distribution

There is an analysis been done at the 13 sec. of pouring time, First we see the Temperature distribution picture Fig. 3 after pouring of metal in to the shell mold. Here we see the uneven solidification of metal so that are chances of Shrinkage and porosity defects.

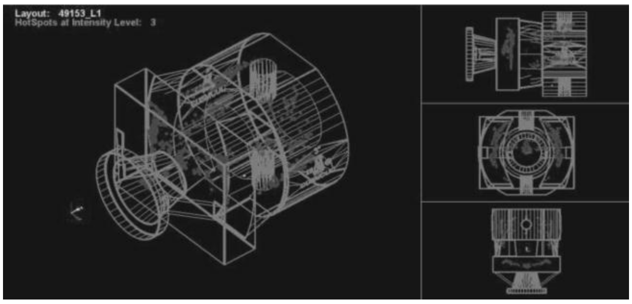

Fig. 4: Hot Spot Prediction at Level 3

Here we see the Hot spot analysis graph at the Level 3 where the Hotspots have to be minimum after that level

The component has the maximum possibilities of defects. Hotspots are the regions where molten metal solidifies last.

Model no.	Runner size	No. of Gate	Gate Size
1	310*210*75	2	200*75*65
2	310*210*40	4	65*60*105

Table. 2: Information about size

III. DESIGN CONSIDERATIONS

1) Average filling rate, Kg/s = Weight of casting/ filling time = 37/13= 2.84 Kg/sec
2) Steel castings: Pouring Time t = K √W seconds = 1.2 √202.47254 = 17 Seconds. Weight of metal to be poured = 202.47254 pounds
3) Yield = Casting Weight / Pouring liquid weight= 37.50 / 82.14 = 45.21 %
4) Solidification Shrinkage of Metal for Steel – 1.5 – 2.0 %
5) Effective Metal Head of casting Hp = H – h_{12}/h_2 = 75 mm
6) Gate Thickness = ½ Local casting thickness = ½ * 67.5 = 33.75 mm
7) Initial Pouring Rate = 1.5 * Average pouring rate = 1.5 * 2.84 kg/sec = 4.26 kg/sec.
8) Gating Ratio = Cup: Runner: Gate = 1: 2: 1.5
9) Casting Material CU5MCUC
10) Weld ability (4) – 2 Satisfactory

IV. MODIFIED DESIGN

In new modified design we increase a no. of gates up to 4 for even solidification of the molten metal and we reduced the height of the runner so that we can increase the yield up to desirable level.

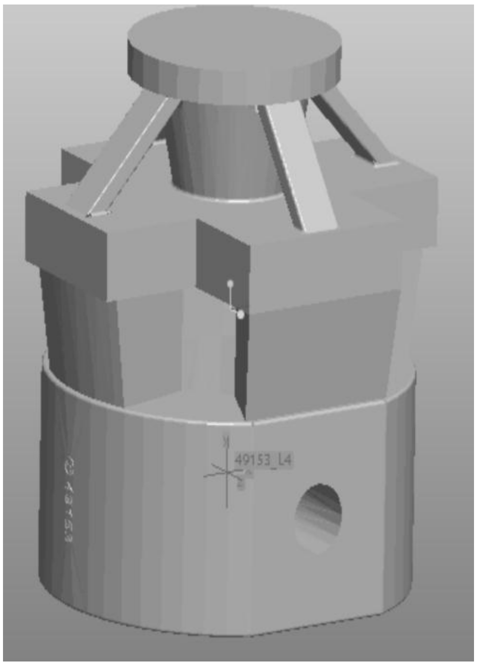

Fig. 5: Modified Gating System

A. *Simulation of Modified Design*

Here we see in the Fig. 6 the graph of temperature distribution of the molten metal in the modified gating of the component. There is an even solidification is there so that there is a less chances of shrinkage and porosity.

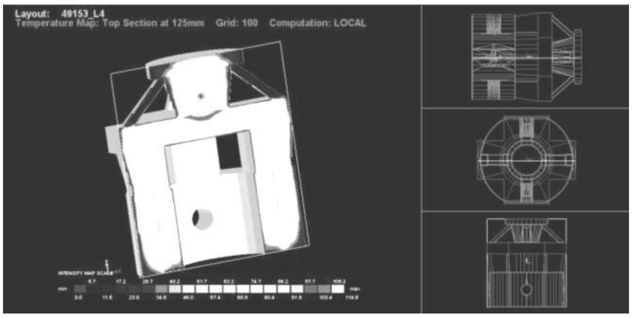

Fig. 6: Temperature Distribution of Modified Gating

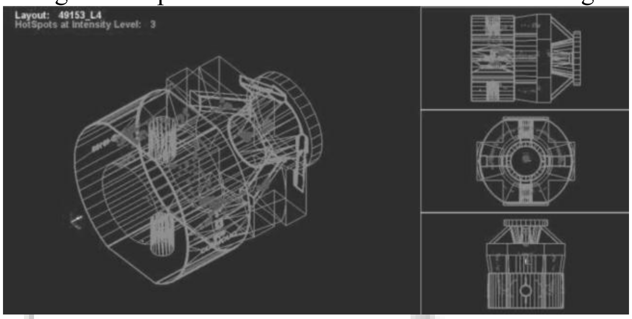

Fig. 7: Hot Spot Prediction at Level 3

As here shown that the Hotspots are reduced compare to the primary gating system Hotspot graph. So, this design is acceptable.

V. INDUSTRIAL IMPROVEMENT

Based on the simulation results, some improvements were done on the site. Number of Gates Increased up to 4 and some Draft been made in that. Runner size has been modified so that Yield has been Increased Significantly.

VI. CONCLUSION

It has also proven to be very useful for verifying the manufacturability of a casting and improving it by minor modifications to part geometry, before freezing the design in early stages of product life cycle. Application of casting simulation software in foundries can be able to optimize the size of runner to avoid shrinkage defect in the casting. The presented model describes depression of the surface during solidification, as well as the formation of shrinkage porosity. Above Results also closely matches with the practical results which show that Simulation is a good tool to reduce costly, time consuming experimental method and improve quality of casting.

ACKNOWLEDGEMENT

We would like to sincerely acknowledge the en-courageous efforts of Mechanical Engineering Department of B. H. Gardi College of Engineering & Tech., Rajkot. Our heartfelt thanks to faculty members who helped us in prepare review paper and give direction with their precious suggestions & rich experience.

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