ISSN XXXX XXXX © 2016 IJESC

Research Article Volume 7 Issue No. 1

Optimization of Gating System and Risering System for Casting of Valve Body using ADSTEFAN Simulation Software

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Abstract:
More than 90% of all manufactured goods & capital equipment use casting for their manufacture. In spite of conventional knowledge of gating system design & suggestions by experience foundry engineers there will be a presence of various casting defects. Producing defect free casting is a challenge in manufacturing environment. Any improper designing of gating system and risering system results in various casting defects. Therefore adequate care is necessary in designing gating and risering system for improve yield of defect free casting. This paper aims to reduce/eliminate the casting defects in valve body by design optimization of gating and risering system by replacing existing trial and error casting method with the help of CAD modeling and simulation software. In this paper modeling of valve body was done in NX V9 (UG) and ADSTEFAN used as simulation software.

Keywords: Casting, Simulation, Gating System, Optimization, Shrinkage, Fluid flow, Solidification, Valve body.

I. INTRODUCTION

Casting, one of the economical manufacturing processes used in industries, is a complicated process, which involves considerable metallurgical and mechanical aspects. The rate of solidification governs the microstructure largely, which in turn controls the mechanical properties like strength, hardness, mach inability, 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 and other process parameters. Wrong designed riser results either defective casting with shrinkage cavity or lower yield, as directional solidification has not achieved. Recently, due to the development of computer technology, an effort is done to predict casting defects directly as a consequence of the physical phenomena that are involved. Casting process simulation was initially developed at universities starting from the early '70s, mainly in Europe and in the U.S., and is regarded as the most important innovation in casting technology over the last 50 years. The objective of the research presented in this thesis is to optimize gating and risering systems based on CAD and simulation technology with the goal of improving casting quality such as reducing incomplete filling area, decreasing large porosity and increasing yield. Casting simulation can overcome the above problems: virtual trials do not involve wastage of material, energy and labour, and do not hold up regular production. However, most of the simulation programs available today are not easy-to-use, take as much time as real trials, and their accuracy is affected by material properties and boundary conditions specified by users. The biggest problem is the preparation of 3D model of the mold cavity with cores, feeders and gating for every iteration, which requires CAD skills and takes considerable time for even simple parts. This also prevents early manufacturability evaluation and improvement by product designers, which can benefit several times more than tooling and process changes. There are number of casting simulation software are developed and are used in foundry worldwide. The application of casting simulation software's 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. The shop floor iterations can be significantly reduced and will be primarily used for concept validation. Many dedicated casting simulation softwares are available today-ASTEFAN, MAGMASOFT, ProCAST, Solid CAST, and AutoCAST. ADSTEFAN(Advanced Solidification Technology for Foundry Aided by Numerical Simulation) is three dimensional solidification and fluid flow package developed to perform numerical simulation of molten metal flow and solidification phenomena in various casting processes, primarily sand casting and die casting (gravity, low pressure and high pressure die casting). It is particularly helpful for foundry application to visualize and predict the casting results so as to provide guidelines for improving product as well as mold design in order to achieve the desired casting qualities. Prior to applying the ADSTEFAN extensively to create sand casting and die casting models for the simulation of molten metal flow(mould filling) and solidification(crystallization in the process of cooling).The cast and mold design of the experiment is transformed into a 3D model and imported into ADSTEFAN to conduct the sand casting process simulation. Much software use finite element method (FEM) to simulate casting process, which needs manual meshing and are prone to human errors. The casting simulation software used in the present work uses Finite Difference Method (FDM) using cubes as the basic elements and has a major advantage over FEM. It meshes automatically eliminates the need to recheck the meshing connectivity there by speeding up analysis. In the present riser system has been designed and optimized by iterative process through fluid flow and solidification simulation for a wheel hub to produce defect free casting [1].

II. LITERATURE REVIEW

There were lot of research work had been done on casting simulation by using different casting simulation softwares Such as Prabhakara Rao et.al [2] have studied on the simulation of the mould filling solidification of casting of green sand ductile iron casting sand concluded that the use of casting simulation software like Pro CAST can able to eliminate the defects like shrinkage, porosity etc in the casting. It also improves yield of the casting, optimize the gating system design and the mould filling.

Shamasunder [3] has discussed the steps which is involved in simulation the possible sources of errors and care to be taken during the casting process simulation. According to him the designer needs to have full confidence in the casting simulation tool. This can come only by experience and usage of the tool to mimic effect of various process parameters. With the advances in technology and proper care in modeling, it is possible to simulate the defects generated during casting before the casting is practically produced. They presented different case studies using ADSTEFAN software.

Maria et al [4], have observed that the application of casting simulation has been most beneficial for avoiding shrinkage scrap, improving cast metal yield, optimize the gating system design, optimizing mould filling, and finding the thermal fatigue life in permanent molds. Several case studies demonstrate the benefit of using these tools under industrial conditions. Now a day, in final and the foundries that cover around 90 % of the production of the cast machine components use casting simulation as an everyday tool. This will demonstrate the application of the ProCAST software. Simulation resulted in gating system and mouding changes that reduced the weight of the total casting from 59 Kg down to 46 Kg.Maintaining casting quality the yield has been increased by 9 %.some experiments were carried out under foundry conditions to compare the results.

DR.B.Ravi *et al* [5], have discussed on the basics of casting simulation .Casting simulation has become a powerful tool to visualize mould filling, solidification and cooling, and to predict the location of internal defects such as shrinkage porosity, sand inclusions, and cold shuts. It can be used for troubleshooting existing castings, and for developing new castings without shop-floor trials. This will describes the benefits of casting simulation (both tangible and intangible), bottlenecks (technical and resource related), and some best practices to overcome the bottlenecks. These are based on an annual survey of computer applications in foundries carried out during 2001-2006, which received feedback from about 150 casting engineers, and detailed discussions involving visits to over 100 foundries. While new developments such as automatic optimization of method design are coming up, a national initiative must ensure that the technology is available to even small and medium foundries in remote areas. Method optimization is useful for both existing castings, and those under development for the first time, by eliminating shop floor trials.

Naveen hebsur [6] work on simulation of sand casting of a flywheel using ADSTEFAN software. Several iterations has been done to obtained a defect free component. Four ingates are provided at the first iteration, after the completion of first iteration the shrinkage defect is occurred. In order to obtain sound cast the model has to be modified in such a way that two ingates are provided at the thicker section of inner rib of flywheel and on which the risers are provided to achieve the directional solidification and hence a defect free component is obtained.

III. MATERIAL AND METHODOLOGY

Valve bodies are cast or forged in a variety of forms and each component have a specific function and constructed in a material suitable for that function.

- For small valves are usually brass, bronze, or forged steel.
- For larger valves, cast iron, cast ductile iron or cast steel as required for the pressure and service.

Table 1: Chemical composition of carbon steel (ASTM A216 WCB)

Element	(Fe)	(c)	(Mn)	(Si)	(s)	(P)	Residuals
Weight	97-100 %	0-0.3 %	0-10 %	0-0.6 %	0-0.045 %	0-0.04%	0-1.0%

Methodology

Valve bodies along with the gating and risering system were generated in NX CAD and the simulation is carried out in ADSTEFAN simulation software. Initially hot spot analysis is carried out to obtain the defect prone area and according to this risering system was designed. Hot spot analysis of a valve body shows that there is a shrinkage prone area near flanges and body. This lead to design of riser to eliminate the shrinkage defect in a valve body.

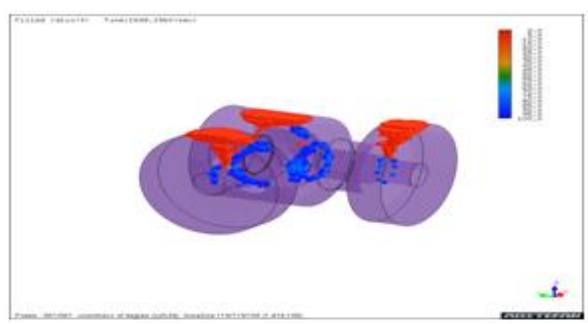

Figure.1. Riser design

Modulus of casting Mc= 2.58 cm
Neck modulus Mn= Mc*1.1= 2.83cm
Feeder modulus Mf= Mc*1.2=3.09cm
For top riser
Diameter of riser = 167.18mm
Height of riser = 250.783mm
Breaker core diameter = 133.7511 mm
Breaker core height = 20mm
Gating ratio = 1:2:1.5

IV. RESULT AND DISCUSSION

Iteration 1

In iteration 1 valve body with riser and square geometry parting line gating system is as shown. The following are the results of iteration 1.

1) Air entrapment

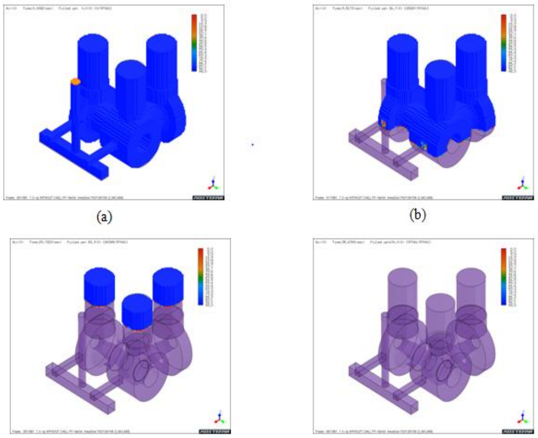

Figure.2. Air Entrapment

The output file air entrapment shows the region where air entrapment likely to occur. In Fig 8.2 (a) blue colour indicates the cavity is completely filled with air before the flow of molten metal. Whereas fig 8.2 (d) grey colour represents the cavity is completely filled with molten metal. Thus from slides a, b, c, d it is clear that there is no entrapment region in the valve body. The air completely escapes from the top of the riser resulting in no air entrapment zone in the casting component.

2) Solidification of pattern

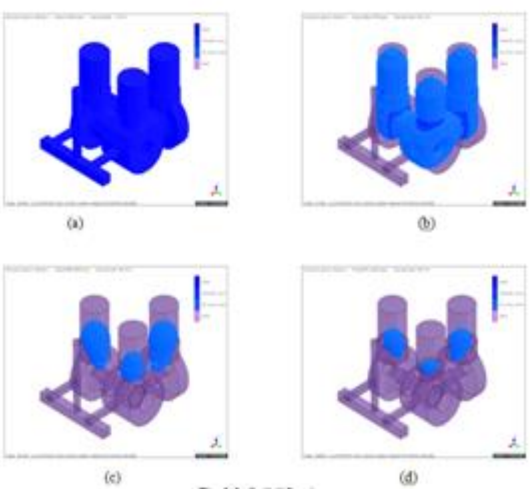

Figure.3. Solidification of pattern

The solidification pattern of the iteration 1 is as shown above. It can be seen that the valve body along with gates and risers are in molten condition at the beginning. As the solidification progresses it can be observed that the solidification starts at the end and works its way towards the riser. Thus it can be concluded that the solidification pattern for iteration 1 is satisfying the directional solidification.

3) Soundness of degree

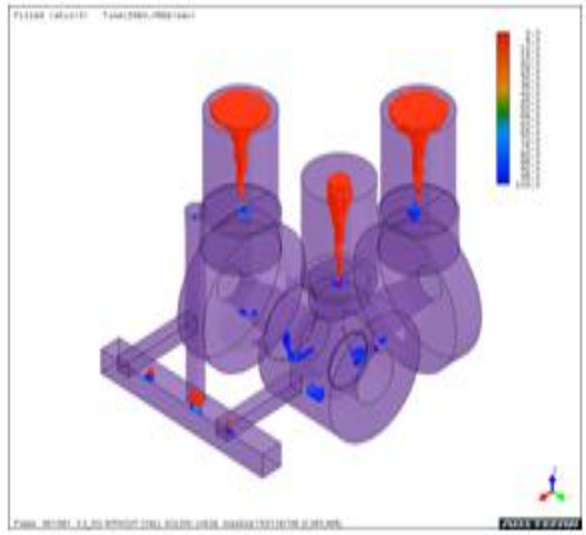

Figure.4. Soundness of Degree

Soundness of degree specifies that our casting is how much defect free. From the below figure it can be observed that there is shrinkage occurring in the valve body. Thus with the parting line gating system there is a shrinkage occurring in the valve body. Thus next iteration is carried with bottom gating system to eliminate the gating system.

Iteration 2

In this iteration bottom gating system along with the aid of chills are used. The following results are noted down.

1) Air entrapment

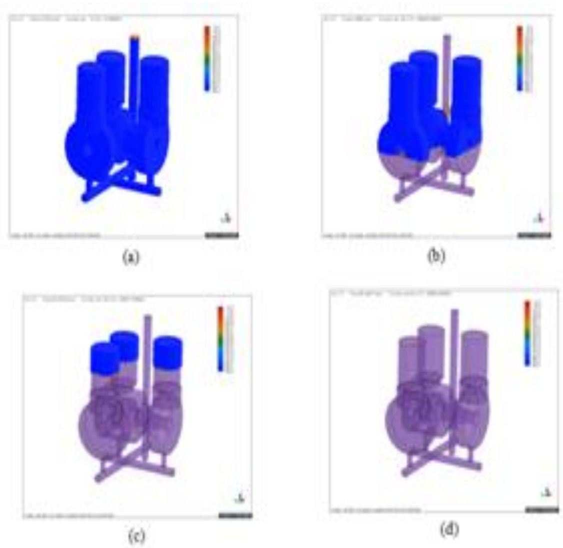

Figure.5. Air Entrapment

The air entrapment result of iteration 3 as shown in the slides above. From the above figures it is clear that there is no air entrapment in the valve body for bottom gating system. Thus the casting is free from air entrapment zone in the component.

2) Solidification pattern

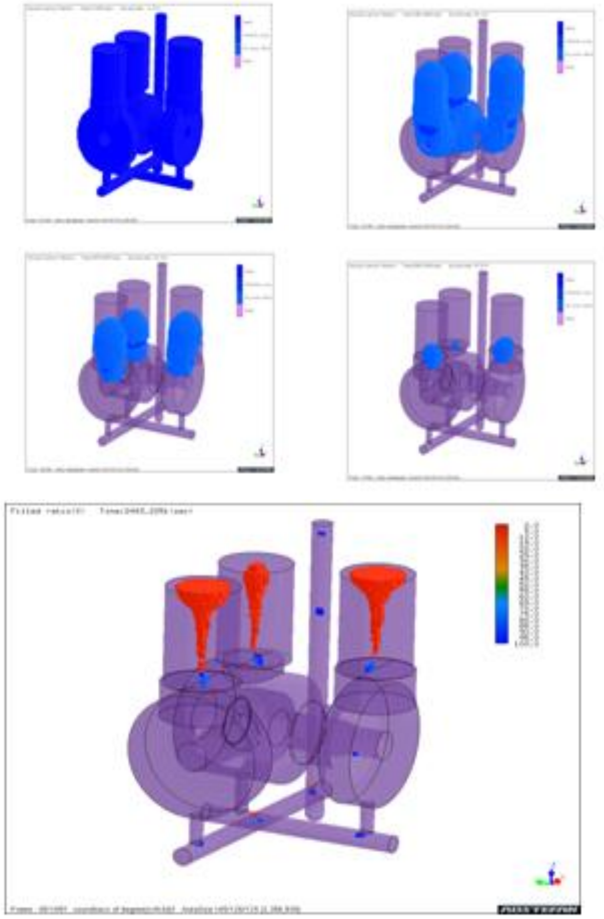

Figure.6.solidification pattern

For iteration 2 the solidification pattern results shown that there is no discontinuity in the valve body and hence leading to directional solidification.

3) Soundness of degree

The results obtained from iteration 2 shows that there is no shrinkage occurring in the valve body. Thus it can be concluded that the results obtained from bottom gate with the aid of chills produces defects free casting. Thus there is no need of next iteration.

V. CONCLUSION

In the present work 3D model of valve body component with gating system is simulated with the ADSTEFAN software to evaluate possible casting defects for sand casting of valve body. Notable conclusions from this study are

- In iteration 1 with square geometry parting line gating system fluid flow was smooth and there is no air entrapment zone in the valve body but shrinkage defect was occurring in the body.
- In iteration 2 with bottom gating system along with the aid of chills we can see that there is no shrinkage defect occurring in valve body.
- Thus we can conclude that bottom gating system is the optimized gating system for valve body.

VI. ACKNOWLEDGEMENT

The author's wishes to thank research paper review committee, Department of Mechanical Engineering. HOD and Principal of Nawab shah alam khan college of Engineering and technology, Hyderabad for their encouragement and support in undertaking the present work. I also express special gratitude to our guide Associate professor Sunil Mangshetty, Senior Application Engineer Santhosh Kumar A. S, ProSIM R&D Pvt, Ltd, Bangalore and Chidanand G, Head-Technical skill Development ProSIM R&D Pvt, Ltd, Bangalore for his inspiration, guidance, constant supervision, direction and discussions in the present work.

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