# Simulation of shrinkage defect-A review

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***Abstract***— **Shrinkage cavity may be detrimental to mechanical performances of casting parts. As a consequence, design engineers often use overly large safety factors in many designs due to insufficient understanding of quantitative effects of shrinkage cavity defects. Now a day casting simulation has become a powerful tool to understand mould filling, solidification and cooling to predict the location of internal defects such as shrinkage porosity, sand inclusions and cold shuts. It can be used for developing new casting without shop-floor trials. This paper describes the benefits of casting simulation and how to reduce shrinkage defect in casting part with Simulation process and theoretical background.**

***Keywords***— Casting, Shrinkage Defects, simulation.

## I INTRODUCTION

Casting is 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 turns 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 and other process parameters. Wrong designed riser results either defective casting with shrinkage cavity or lower yield as directional solidification has not achieved

From realistic considerations the experimental results are always better for design and development of mould and for arriving at the optimum process paramaeters.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'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 [1]. Many dedicated casting simulation softwares are available today-MAGMASOFT, ProCAST, SolidCAST, and AutoCAST. Modules of typical casting simulation software are shown in Fig.1 [2].

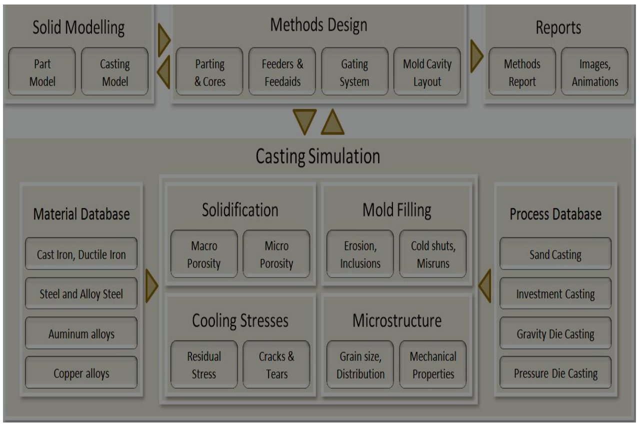


Figure. 1 Different modules of casting simulation system [2]

The main inputs for the casting simulation process are:

- The geometry of the mould cavity (3D model of the casting, feeders, and gating channels).
- Thermo-physical properties (density, specific heat, and thermal conductivity of the cast metal as well as the mould material, as a function of temperature).
- Boundary conditions (i.e. the metal mould heat transfer coefficient, for normal mould as well as feed aids including chills, insulation and exothermic materials).
- Process parameters (such as pouring rate, time and temperature).

### *Casting defects*

A casting defect is an irregularity in the metal casting process that is undesires.some defects can be tolerated while other can be repaired otherwise they must be eliminated. They are classified into five main categories: gas porosity, shrinkage defects,mould material defects, pouring metal defects and metallurgical defects. As shown in fig 1.1 and fig 1.2 diff casting defects-porosity.

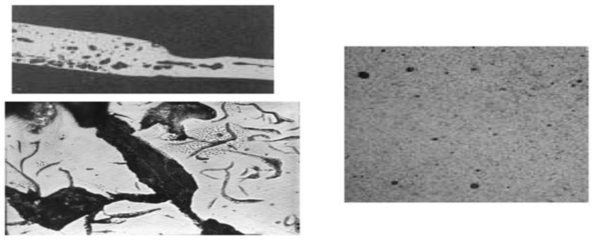

Figure 2: Different Casting Defects-Porosity

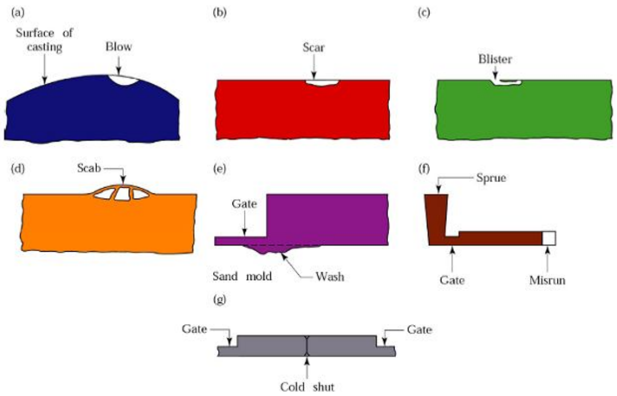


Figure 3: Different type of defects

**Shrinkage defect**

Shrinkage is reducing the volume of the casting material when metal is cooling and solidifying. So produce the Line, holes in the casting its called the shrinkage defect. Shrinkage is a volumetric Differences between solid and liquid phase during solidification in casting. casting section is solidify later than surrounding section so metal flow not complete fill the casting area. [3]

***Types of Shrinkage defect***

(1) Outer sunks (pull down)
(2) Micro shrinkage
(3) Macro shrinkage
(4) Porosity

(1) Outer sunks (pull down)

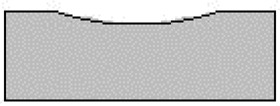

Figure 4 Courtesy [4]

This defect is seen on the outside surface of the casting, also seen on thick section of casting part. There is some depression on surfaces. It's also called the "pull down" shrinkage defect. [4]

(2) Micro shrinkage

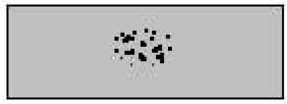

Figure 5
Courtesy [4]

These defects are seen in near the area of the heat. This defect is also called the"leak defect". Micro shrinkage defect is and irregular shape with dendrites and small cavity.Micro shrinkage is not seen with naked eye. It is seen after the machining of the part [4].

(3) Macro shrinkage

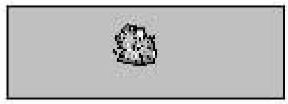

Figure 6
Courtesy [4]

Macro shrinkage is inside of the casting part and near of the heat area. This is like to hole in the casting a larger 5mm length. Its near to the ingate[4].

(4) Porosity

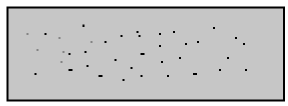

Figure 7
Courtesy [4]

Porosity is like small hole of 1mm size on the Surface of the casting part. Its hole seen in water testing of casting part. This defect is seen near the area of grain boundaries and heat area. [4]

***Causes and remedies of shrinkage defect***

(1) Outer sunks (pull down)

Causes :-

Liquidus temperature of metal is too high.Insufficient clamping of mould. [4]

Remedies:-

Short flow length so pouring at low temperature. High flow length so pouring at high temperature. To minimize the volume contraction in the liquid

State. [4].

(2) Micro shrinkage

Causes:-

Alloy have long freezing point. Thermal conductivity of metal is high. Mould temperature is high. Mould thermal conductivity is low.Its depends on change of phase. [5]

Remedies:-

Reduce the riser contact modulus. Modulus of the ingate feeder to the riser is reduce. Need of many risers. [6]

(3) Macro shrinkage

Causes:-

Feeder modulus is too small. Feeder position is wrong. Material liquids temperature is, higher than normal temperature. [4]

Remedies:-

Increase the riser size. [6] .Feeder material is available to long. [4]

(4) Porosity

Causes:-

Incorrect spruing. Flask temperature too hot. [7]

Remedies:-

Sprues should be attached to the heaviest piece of the casting. There should be sufficient sprues to ensure the casting is adequately fed.

The flask temperature should be just hot enough to achieve complete fill. [7]

Today, advanced simulation could be used to understand and control such a complex behaviour. Indeed, heat flow, solidification, fading effect, graphite/austenite eutectic transformation, ledeburite eutectic transformation, graphite growth in the austenite regime, and the eutectoid transformation could all be modeled. In ProCAST TM, a comprehensive micro model was developed which can give accurate micro structural in-formation as well as the mechanical properties, such as yield strength, tensile strength, elongation and hardness. The fractions of austenite, ferrite, pearlite, graphite, liquid, and ledeburite are all calculated. The micro model together with thermodynamic database has been coupled with the porosity model allowing an accurate shrinkagePrediction by taking into account the complex phenomenon of graphite expansion. The predictions have been compared with experimental results.

The goal of this study was the improvement of the casting process using the softwareProCAST, which is tailored to casting simulation and solves the heat transfer problem by the finite element method (FEM). The aim of the foundry was to reduce the remelting and refinishing metal but obtain at same time a high quality casting. In the present case they had a lower amount of saleable casting from a given amount of liquid metal, driving a yield of 34 %. In order to evaluate the applied methodology, the foundry has done a new model and several castings were produced. To compare the quality of the parts some cuts were made at the castings.

***Casting simulation***

This includes mould filling, solidification, grain structure, stresses and distortion. It requires solid models of product and tooling (parting, cores, mould layout, feeders, feedaids and gates), temperature-dependent properties of part and mould materials, and process parameters (pouring temperature, rate, etc.). The simulation results can be interpreted to predict casting defects such as shrinkage porosity, hard spots, blowholes, cold shuts, cracks and distortion. The inputs however, require considerable expertise and may not be easily available to product designers. One solution is to involve tooling and foundry engineers in the product design stage, and evolve the product, tooling and process designs simultaneously, ensuring their mutual compatibility with each other. This approach is referred to as concurrent engineering.

***Methodology***

Figure 6.1 shows a flowchart, in which 3D CAD and simulation tools are utilized to improve the system design of the casting. The castings geometries presented here were meshed with MeshCAST, which requires the generation of a surface mesh before meshing the enclosed region with tetrahedral elements. The computational conditions used in all simulations were the same. Figure 6.2 shows a flowchart, where is represented the steps needed to make a simulation.

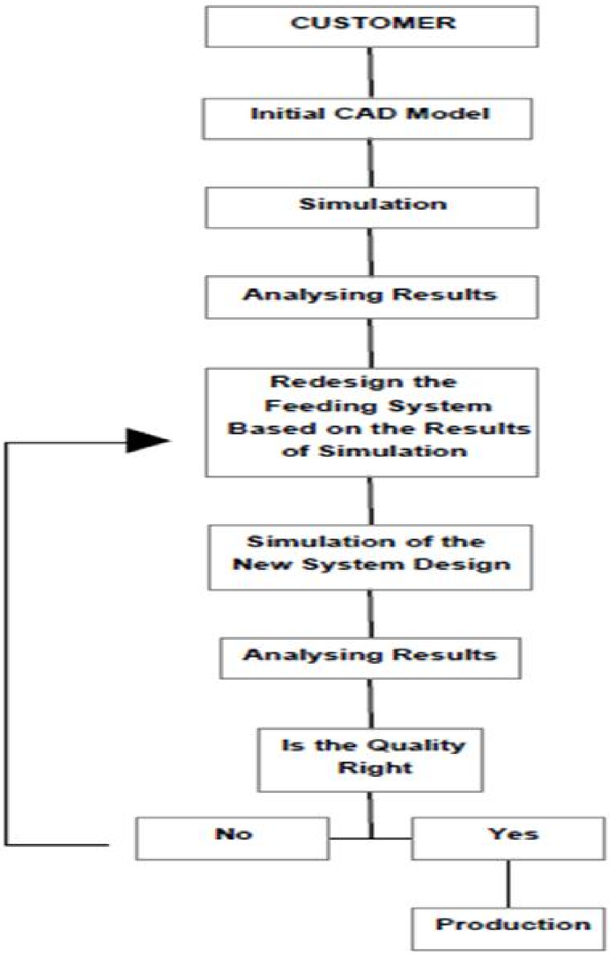


Figure 8 Procedures to improve the design of new casting.

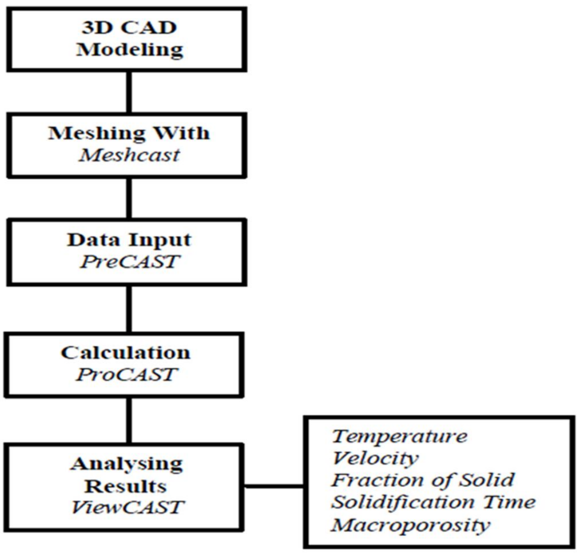


Figure 9 steps needed to make a simulation

## 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 [9] 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 [8] 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 [10], 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 covers 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* [11], 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 (Fig.10).

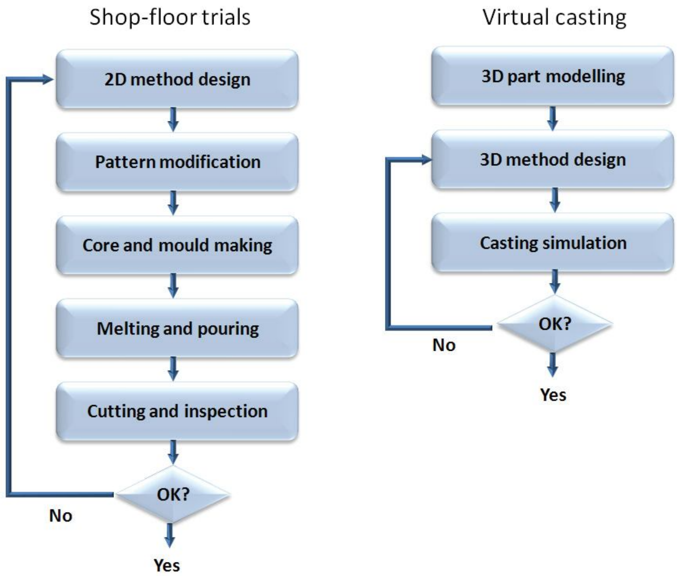


Figure10 Comparison of manual and computer-aided method optimization

A proper benchmarking of simulation programs by live demonstration can prevent many unpleasant surprises later. The programs are gradually become more powerful, by including method design suggestions, automatic modeling of feeders and gating system, and user-guided optimization for achieving the desired quality at the highest yield. In near future, we will be able to get the castings right first time, every time, in real time.

AutoCAST, MAGMASoft, ProCAST and SOLIDCast have the largest installation base in india. Companies who have adopted this software have great advantages in their process.

*The process of casting:-*

1. Making of core
2. Gate –Riser Position
3. Die Heating
4. Core setting in die
5. Pouring of metal
6. Proof machining.
7. Shot Blasting
8. Testing

CONCLUSION

Casting simulation technology become a powerful tool for casting defect troubleshoot in and method optimization. It will reduce the lead time for the sample casting; improved productivity and knowledge of sotwares can be maintained for future use and for training new engineers in this caster's field. In the casting design process, mostly shrinkage defect occur in most of part. In practice, these defects are eliminated by iteratively designing casting filling (gating) system through experience and experiments, but it requires large number of shop floor trials; taking huge amount of resources (cost) and time. This can be avoided by conducting trials on computer using casting simulation technology.

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