Sand Casting Simulation: A Review

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Abstract: Foundries represent an important sector of the manufacturing industry. Sand casting is commonly used in foundry. This paper presents study of sand casting simulation using the simulation softwares. There are some inputs and outputs of the software. For the accurate results, each and every input parameter affects the results of simulation. There are different softwares are available in market for the simulation of casting. Sand casting simulation helps to increase the quality and yield of casting with minimum time and significant accuracy. The various casting defects are observed and eliminated through simulation. Simulation softwares are used for the optimization of yield of casting.

Keywords: **Sand Casting, Casting Defects, Casting Simulation.**

I. Introduction

Casting simulation technology is an emerging technology that is being used to increase the efficiency of casting design processes (i.e. gating design). Traditional foundry practices in this area range from simple adaptations of standard designs to using engineering methods to estimate the appropriate dimensions of the casting component and gating system. Simulation is the process of evaluating a real phenomenon using a set of mathematical equations implemented in a computer program. Simulating metal flow and solidification can improve casting design and help signify the cost effectiveness of different design variables. This can be achieved prior to the casting and can significantly reduce lead times.

There are different software's are available for simulation of sand casting component as follows

i. Solid CAST
ii. MAGMA soft
iii. Pro CAST
iv. AutoCAST

While the underlying physical phenomena is the same, they differ interms of the discretisation (divides in small parts) of space and time continuum, handling of various material properties (ex. Thermal coefficient of expansion), boundary conditions (metal-mould interfacial heat transfer coefficient), and the numerical computation employed. The finite difference method (FDM) and finite volume method (FVM) use cubic or brick-shaped elements, finite element method (FEM) uses tetragonal or hexagonal elements, and vector element method (VEM) uses a combination of cubic and pyramidal elements. The FEM approach gives the casting shape more accurately (using fewer elements), but may require manual effort to correctly generate the element mesh, which can sometimes take more time than the computation itself. Among of all this, autoCAST is the more user friendly and accurate simulation software.

II. Literature Review

B. Ravi [1, 2] gives us the guidelines for effective implementation and use of casting simulation technology. The guidelines are based on a review of about 200 industrial projects carried out by simulation consultants associated with IIT Bombay. The projects are of two types: (a) quality or yield improvement of existing castings, (b) rapid development of new castings and (c) yield improvement of existing gating system. The guidelines gives the all major metals and processes and deal with five stages of simulation projects: data gathering, methods design, numerical simulation, methods optimization and project closure.

Vivek Gondkar and Inamdar [3] has optimized casting process parameters through simulation and predicted that change in feeder location causes minimization of hot spots. The defects like cold shut, shrinkage porosity and hot spots and optimize the casting design to achieve the desired quality with high yield. Minimization of rejection takes place up to 0.2%. the time required very less to conventional method of design of methoding. The outcome of this paper is improved casting quality, reduction in rejection rate, reduced cost of rejection, increased efficiency and increase in yield of casting. Visualization of mould filling phenomenon gives the proper direction to user for analysis of process.

P.Saxena et.al [4] have minimized the casting defects such as Shrinkage, sand drop, sand blow holes, scabs and pinholes by using Taguchi optimization technique. The parameters considered are moisture content, green strength, mould hardness sand practical size. The Taguchi approach is used to capture the effect of signal to noise ratio of the experiments based on the orthogonal array used to find the optimum condition. This paper gives idea to select suitable process parameters in casting industry to produce defect free castings. The improvement expected in reduction of casting defects is 20-30%.

Shinde et al. [5] have suggested a methodology to optimize mould yield by selecting the correct combination of the mould box size and the number of cavities based on solidification time and mould temperature. Simulation studies have been performed by modeling solid and hollow cube casting with different values of cavity wall gap and finding the minimum value of the gap. He studied that there is no change in part solidification time beyond minimum value of gap. Then double cavity moulds were prepared with different values of cavity-cavity gap and simulated to find the minimum value of gap.

Choudhari et al. [6] stated that the cast part solidification process is complex in nature and the simulation of such process is required in industry before it is actually undertaken. The defects like shrinkage cavity, porosity and cold shuts can be reduced by designing an appropriate feeding system to ensure directional solidification in the casting, leading to feeders. The use of a simulation model helps to study real life systems which are imaginary. In particular, one is interested in quantifying the performance of a system under observation for various values of its input parameters. Such observed measures of performance can be very useful in the managerial decision process. The cost concerns of the metal casting company targets on the extra time and energy spent in replacing the setup configurations in the manufacturing system. [7].

Renukananda et al. [7] have studied that flow of water as well as LM6 aluminium alloy passed through multi-gate gating system is used to compared by using numerical simulation. Casting process having so much variations in type of materials, type of patterns, type of mould and pouring skills like in green sand casting, die casting, investment casting, squeeze casting, lost foam casting. In all these process the most widely used process is the sand casting process, it helps to produce the intricate parts.

III. CASTING SIMULATION

Need of simulation

Computer simulation of sand casting process has an emerged as a powerful tool for achieving quality assurance without time consuming trials. Software packages are available for simulating the solidification of molten metal in the mold enable predicting the location of various defects (like shrinkage porosity) and optimizing the design of feeders to improve the yield; more advanced packages with large numerical computation perform coupled simulation of mold filling and casting solidification. Casting simulation should be used when it can be economically significant for the following three reasons:

- **Quality improvement** by predicting and eliminating internal defects like shrinkage porosity, mis-run, cold shut.
- **Yield enhancement** by reducing the volume of feeders and gating channels per casting
- **Rapid development** of a new casting by reducing the number of foundry trials with minimum rejection rate.

Casting simulation programs are generally used for analyzing:

i. Mould filling
ii. Casting solidification
iii. Internal stresses and distortion
iv. Microstructure and mechanical properties

The simulation programs are based on Finite Element Analysis (FEA) of 3D models of castings and involve high complexity functions for user interface, computation and display. Casting simulation has proven large benefits. The software also facilitates electronic exchange of information between product data, tooling method and skilled casting engineers, improving the level of communication between them and helping for compress the total lead time to complete a project. They are developed over several years and involve several hundred thousand lines of code for the numerical calculation. The casting model (with gating system) has to be created using a solid modeling system and imported into the simulation program. In addition, material properties (density, thermal conductivity, specific heat, latent heat, etc.) and process parameters (pouring time, pouring temperature, casting to mold heat transfer coefficient, thermal coefficient of expansion) have to be provided by the user. The later may require extensive experimentation to customize the software database for a particular organization. After executing the simulation process, the results can be post-processed to view color-coded temperature profile, velocity vectors or residual stresses and the defects occurred in component.

IV. BENEFITS OF CASTING SIMULATION

Some benefits of casting simulation are described in terms of improved quality and yield, reduced shop floor trials, value addition, knowledge management:

i. Improved quality and/or yield:

Simulation and method optimization of sand castings already in regular production leads to improvement in their quality or yield, sometimes both. Every casting process, by virtue of its geometry, material and process, has an optimal method. The design of most castings is incorrectly designed, under-designed, or over-designed. This can be clearly and easily visualized by simulation process, and verified by matching the simulated and actual observations. Often, only minor changes to the method are required: such as placing a insulating sleeve on a feeder, or a chill at a suitable location. Even a minor improvement in yield can give significant saving of resources, or higher productivity (more saleable castings from the same resources) over a period. The cost of poor quality components (machining, transportation, repair, replacement) is becoming substantial, which can be significantly reduced by simulation and optimization.

ii. Reduced shop-floor trials:

Shop-floor trials taken for developing a new casting not only add to its cost, but also divert resources from regular production of other castings. The cost of a shop-floor trial includes tooling modification, melting, pouring, fettling, inspection, and some loss of materials (which cannot be recycled). In the case of large ferrous castings the melting cost is higher, whereas for complex-shaped non-ferrous castings produced in metal dies the tooling modification cost is higher. In another case, virtual casting trials on a software are less expensive and faster, implying that more trials can be carried out to achieve better quality and yield of casting. At the end, only a single foundry trial is sufficient to verify the method design and simulated results.

iii. Value addition:

Simulation programs increase the level of confidence in a foundry for taking up more difficult castings components (complex, large), which typically command a higher margin. They also provide a scientific and documented basis for quality assurance and certification. For example, simulation can point out all probable locations of internal defects occurred in casting component, which can be more carefully observed by sectioning or non destructive testing (NDT) methods. Indeed many overseas customers prefer to do business with foundries having access to casting simulation facility. Thus simulation technique become a valuable aid to marketing the capabilities of a foundry, leading to more and higher value orders.

iv. Knowledge management:

This is an important area, but less appreciated benefit of casting simulation. Since the computer programs automatically stores all input data and results of each virtual trial, it can be readily recalled months or years later, and reused for new projects similar to a previous one. The project report data and presentations can also be used to train new engineers. Finally, the use of CAD modeling and simulation tools in a foundry makes it more attractive for hiring and retaining younger engineers.

V. DIFFERENT FEATURES OF SIMULATION

Casting simulation requires the inputs for the simulation like part design, gating system. After simulating component, it gives the outputs like visualization of mold filling, solidification. Figure 1 shows the basic inputs and outputs of the simulation software. The simulation requires data for giving the inputs for numerical computation. This data acts as the boundary conditions to the mathematical calculation. As numerical computation progresses the results are starting to generate information of results. A result of simulation depends upon the input data provided to software. So data provided should be the correctly gathered from various sources. This software takes minimum time for results rather than experimental approach in foundry.

The different inputs and outputs are goes through following steps

1. Start – In start module, the .stl file of casting part supposed to be browse in software. Material composition, mold size and process type are selected in module.

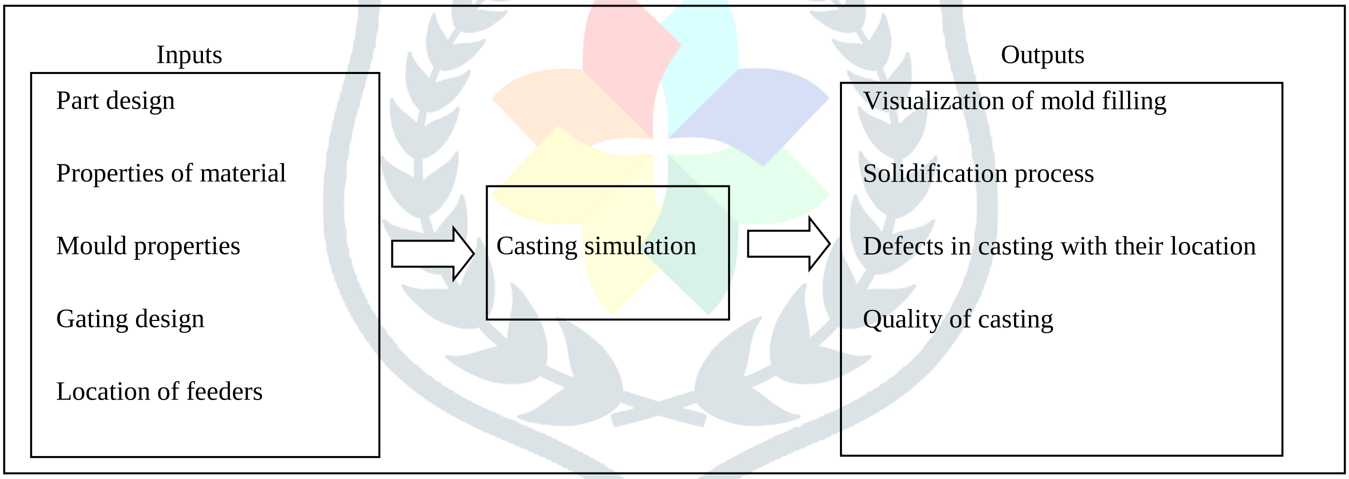

Fig 1: Casting simulation

2. Part design – In this module, properties of component, thickness and holes are required to specify with proper dimensions.
3. Mould design – In this module, mould specification like mould material, core material with these properties are required to specify.
4. Feeder system – In this module, design of feeder with location created in the casting component. Shape of feeder is required to select from the given library.
5. Gating system – Gating system includes runner, riser and ingate. In this module, dimension and shape of runner and ingate are required. Gating system controls the mould filling process. Mould filling is complex phenomenon influencing both internal and external.
6. Flow visualization – Actual simulation performed in this module. In this, virtual filling of mould cavity and the solidification of the cavity are seen through animated format. Solidification time and liquid fraction are identified in module.
7. Results – Results gives the quality of the casting component. Defects occurred in casting components are shown with its position. Shrinkage porosity, blow holes, cold shut, unfilling (misrun) and hard zones shown by the its position and intensity.

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