

Design and Optimization of Gating and Feeding System for Casting: A Review

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ABSTRACT

In the global competitive environment there is a need for the casting units and foundries to develop the components in short lead time. Casting as a manufacturing process to make complex shapes of metal materials in mass production may experience many different defects such as gas porosity, pin holes, blow holes, shrinkages and incomplete filling. The Gating/riser system design play very important role for improving casting quality. Due to the lack of existing theoretical procedures the designing processes are normally carried on a trial-and-error basis. The main objective of this paper is to design and optimize gating and riser system by using various types simulation software with the goal of improving casting quality such as reducing gas porosity, pin holes, gas holes incomplete filling area and increasing yield. This reviews paper considersthe idea about the design and optimization of gating and feeding system which is based on CAD and simulation technique. The runner and risers are design accordingly, and generated CAD models by varying parameters can be used in the simulation software. After analyzing simulation results with old design and compare, the gating/riser system design is optimized to improve casting quality.

Keywords— Casting Design, Casting Defects, Design and Optimization, Gating System, Simulation, Simulation software (Auto-CAST X1)

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I. INTRODUCTION

Gating and Feeding system plays very important role for any casting. Risers are used for compensating for the solidification shrinkage which occurs during the process of solidification [1]. Generally this can be visualized as if these sections feed thinner sections; so, thick sections experience deficiency of molten metal at last and that location contains no metal resulting in defects such as shrinkage cavity. For any newer casting, the development of gating and feeding system takes huge amount of time, cost as well as man power for the manual trial and error method. Sometimes, existing method of castings does not serve its purpose and need modification. All these problems can be effectively handled by Casting Simulation technique [2-3]. Simulation involves construction of mathematical models for any

physical process and performing repetitive iterations on those models so as to predict the behaviour or growth of the process. In case of castings, the simulation software is already developed to provide artificial environment of foundry for performing experiments virtually. Web resources are also available now to run basic simulation which eliminates need of expensive software. Casting simulation comprises of three modules namely Solidification, Flow and Coupled simulations. Out of these three, Solidification simulation can be used to detect locations of hot spots and show the feed-paths; hence it can be used for designing and modifying the feeding systems [4]. Flow simulation can give the idea about velocity of molten metal during mold filling, filling time and solidification time. Which in turn helps to locate flow related defects such as cold shuts and misrun etc.

II. LITERATURE REVIEW

The literature review mainly focusing on design and optimization technique based on casting related defects and their research and outcomes. The details of literature review have been classified in following categories.

2.1 Design and Optimization of gating system

The design & optimization of runner and gating system for the die casting of thin-walled magnesium telecommunication part through numerical simulation discussed Hu et. Al [6]. Suggested that the well-designed runner and gating system is very important to secure good quality die castings through providing a homogenous mold filling pattern. Two types of runner and gating systems were designed and analyzed. A preliminary design with a split gating system led to a swirling filling pattern and insufficient central flow, which spontaneously closed the edges and left the last filled areas falling into the inner portion of the part. After that, a high possibility of air entrapment was found in the casted part and then examined the suggested gating system was not proper and improved by using a continuous gating system and a large size runner. After that change was made by increased the gate area and the gating speed reduced slightly. Numerical simulation showed that this new design provided a homogenous mold filling Pattern and the last filled area was located at the upper edge of the part, where overflows and the vents were conveniently attached. Bhatt H. and Barot R.[7] has suggested that the design optimization of feeding system and simulation of cast iron in foundries can reduced the casting defects which were arise during solidification and filling process. Time to changed riser and feeding system dimensions and simulate with the help of Auto-CAST software and validate it and found reduction in hot spot and shrinkage porosity and cracks in gear box of automobile components. Zhizhong s et al. [8], suggested that the numerical optimization of gating system parameters for a magnesium alloy casting with multiple performance characteristics in magnesium alloy base casting to analyzed the effect of various gating system design on cavity filling and casting quality using simulation results indicated that gating system design affects the quality of casting, four gating system parameters were changed namely ingate height, ingate width, height of runner and width of runner for casting model of magnesium alloy, designed and simulated mold filling and solidification processes through MAGMASOFT software and satisfactory results obtained with high yield and reduced shrinkage porosity.

2.1 Defect Minimization By Casting Simulation

The casting design and simulation of cover plate using autocast-x software for defect minimization with experimental validation studied Chaudhari C.M and Narkhede B.E [9], suggested that the significant improvement in the quality of casting obtained by optimization of location and design of gating and feeder system through simulation technology and minimized shrinkage porosity and cracks in casting.

Sun y. and Luo J. [10], studied the numerical simulation and defect elimination in the casting of truck rear axle using a nodular cast iron and analyzed the reasons of some typical defects such as shrinkage porosity shrinkage cavity, cold shut, and hot spot and crack, which take place in the casting processing by applying nodular cast iron to the truck rear

axle. Simulation software are used to study the casting solidification of the rear axle, which is made from nodular cast iron the height of the ingate is increased, and the length of the ingate is shorted, the horizontal size of runner is longed, the diameter of the sprue bottom part which is located in the middle of the runner is increased and the position of the riser is also changed. The simulation research results and experiments show that these optimization methods are promising to reduce the casting defect and to improve the product quality by using Z-cast and CAD engineering modeling software. Hassan et al. [11] investigated the impeller shaped casting using MAGMASOFT Software. The effect of the location and size of feeders and gates on parameters such as pattern filling, velocity and pressure, rate of cooling, solidification and major and minor defects were studied. The existing results were then compared with experimental data, and an excellent agreement between them was reported.

2.3 Effect of Gating System On Mold Filling

The effect of gating system design on mold filling for light metal casting and experimental studied Masoumi et al. [12], results shown that the geometry and size of the gate and the ratio of the gating system has a great influence on the pattern of mold filling and suggested that the application of computer aided design method, and casting simulation technique in foundries can minimize the bottlenecks and non-value added time in casting improvement, as it reduces the number of trial casting required on the shopfloor. Here an attempt has been made to solve the shrinkage defects occurring in an industrial component using AutoCAST-X software.

2.4 Solidification Analysis of casting

The study of simulation on the mould filling and solidification, of casting which is green sand ductile iron concludes that use of casting simulation software like ProCAST can able to eliminate the defects like shrinkage, porosity etc. in the casting. It also helps in improving the yield of the casting and at the same time optimization of gating system is done. Similarly shrinkage cavities and other defects may be determined by solidification pattern inside the casting. Simulating the solidification process in the casting simulation software and analyzing it will give the position of porosity inside casting. M.Sutaria et. al. [13] worked on a new idea where optimization of casting feeding is done with the help of feed paths. The computation of feed-paths is done by method known as Vector Element Method (VEM). By this method it is possible to know from a given point the direction of feed metal can be identified. It clearly indicates where the shrinkage porosity may develop by showing the feed paths converging at some point in the casting. And the rest of work is done by the FEM based simulation for visualizing the casting feed paths in a better way. This method is used for benchmark Al-alloy casting where feeder optimization is done with the help of VEM based software. Ravi et al. [14] worked on computer-aided casting design and simulation. This paper describes a much better and faster insight for optimizing the feeder and gating design of castings. Used intelligent assistant for casting engineers like AutoCAST and describes how it assists in designing, modeling, simulating, analyzing and improving cast products.

III. DESIGN METHODS

- 3.1 Gating system:** The elements of gating system include pouring basin, sprue, sprue well, runner and ingate, in the sequence of flow of molten metal from ladle to the mould cavity.
- **Pouring Basin**-It is the funnel-shaped opening, made at the top of the mold. The main purpose of the pouring basin is to direct the flow of molten metal from ladle to the sprue.
 - **Sprue and Sprue well** -It is a passage which connects the pouring basin to the runner or ingate. It is generally made tapered downward to avoid aspiration of air. It is located at the base of the sprue. It arrests the free fall of molten metal through the sprue and turns it by a right angle towards the runner.
 - **Runner** - The fluidity length of the molten metal is less than the maximum distance required to be travelled by the molten metal along the flow path. So it is necessary to provide the multiple ingates to reduce the maximum flow distance needed to be travelled by the molten metal.
 - **Ingate or Gate**- It is a small passage which connects the runner to the mould cavity. The cross section is square, rectangular and trapezoidal.
- 3.2 Feeder system:** Designing a proper feeding system to account for the solidification shrinkage for a cast is guided by six main feeding rules.
- Heat transfer criterion: The feeder must solidify at the same time or later than the casting.
 - Mass transfer criterion: The feeder must contain sufficient liquid to meet the volume-contraction requirements of the casting.
 - The junction requirement: The junction between the feeder and the casting should not create a hot spot, i.e. be the last to solidify.
 - There must be a path to allow feed metal to reach feeding points.
 - There must be sufficient pressure differential requirement to cause the feed material to flow in the right direction.
 - There must be sufficient pressure at all points in the casting to suppress the formation of cavities.
 - Chill should be sufficiently thick so as not to fuse with the base metal. ($0.6 \cdot T$)
 - Chill should be clean, free from dents and dry.

IV. OPTIMIZATION TECHNIQUE

There are many types of optimization technique used in casting processes for the purpose of sound casting like Design of experiment (DOE), Multi-objective evolutionary algorithms(MEOA), Computer aided design and Simulation and so on.

4.1 Multi-Objective Evolutionary Algorithm (MOEA)

Multi-Objective Evolutionary Algorithm (MOEA) is developed to overcome complexity. The proposed optimization framework is applied to the gating and riser design of a sand casting. It was shown that the MOEA method yields good results and provides more flexibility in decision making. In a multi-objective problem, the aim is to find a set of values for the design variables which optimizes

a set of objective functions simultaneously. Multi-objective evolutionary algorithm (MOEA) is a vector optimization approach that tries to find as many different Pareto-optimal solutions as possible and spread them over the entire Pareto optimal front. The main advantage of this method is that the results are independent of any decision making process. Using this approach, inconsistencies in the problem formulation (e.g. weight settings, penalty formulations etc.) caused by the variation of individual knowledge and experience can be eliminated improved.

4.2 Computer Aided Design and Analysis Technique

Computer Aided- Design and Analysis is a scientific approach to casting design and Simulation of cast part which is supported by software tool. It is a Vector element method(VEM) and commonly used in analysis of casting components. This approach accomplish many processes like design of mold, design of gating and riser system, temperature distribution, cooling rate, simulation of casting, defect analysis, solidification analysis, filling and flow rate of cast metal inside the cavity and cost estimation of casting etc. In that, import a CAD model which is made by any CAD software like CATIA, Pro-ENGINEER, Auto-CAD and etc. There are five distinct stages in casting simulation projects past data collection, Design and Modeling, and Numerical Simulation, method Optimization, and Project Conclusion. It is a very economical method and less time consuming process.

V. NEED OF SIMULATION

Casting simulation should be used when it can be economically justified for at least one of the following three reasons;

- a) **Yield improvement** by reducing the volume of feeders and gating channels per casting
- b) **Quality enhancement** by predicating and eliminating internal defects like porosity
- c) **Rapid development** of a new casting by reducing the number of foundry trials. The corresponding cost benefits can be estimated.
- d) **Quality improvement** reduces the costs associated with producing defective castings, including their transports, and warranty or penalties.
- f) **Yield improvement** reduces the effective melting cost per casting, and increases the net production capacity of the foundry.

VI. SIMULATION SOFTWARES

The most common simulation software available in India like, Pro-CAST, Auto-CAST, MAGMA Flow, and Mold flow analysis etc. which is very helpful for benchmarking. The programs employ different methods for casting simulation.

6.1 Auto-CAST: It is a vector element method. AutoCAST-X1 provides a complete solution for casting methods design and optimization. This is the first method, in that Part Analysis (Design for Manufacture) import a part model from any CAD program, and checks its features (thickness, cored holes) for manufacturability. Second method is Method Design (Mold layout, Feeders, Gating) in that Select the number of cavities, position of feeders and gating channels. The software automatically designs, models, and generates the complete mold layout. Third

method is Quick Simulation (Mold Filling and Casting Solidification) in that Verify the methods design by checking for possible defects like mold erosion, filling time, and shrinkage porosity through casting simulation. Last is Costing and Report in that Check the yield, estimate tooling and other costs, and generate a complete report of the methods design with an image of the casting.

6.2 Mold Flow Software: It is also known as mold flow design software. In injection molding, molten plastic is squirted under high pressure into mold. Different flow and cooling rates of plastic can cause flow marks on the surface and wrapping of the finished product, which makes it look untidy. Designing a new mold is often the most expensive single investment in product development- so it's better if you find out where problems might happen before you actually make the mold. That's why the mold flow computer software comes in. It simulates injection-molding process, trailing any shape of mold that the designer can imagine. It display color coded picture of the way molten plastic will flow into the mold and how plastic will shrink or wrap when it cools. Engineers can use this information to design extra cooling channel into the mold and to beef up plastic section that might warp. The toolmaker uses the computer-generated design to make the mold. Using mold flow, designs for plastic product can be completed without the immense cost of making models or testing and modifying or prototype mold.

CONCLUSIONS

It has been observed that, the solidification simulation enables visualization of the progress of freezing inside a casting and identification of the last freezing regions or hot spots. This gives the better results as follows,

- This facilitated the optimized placement and design of feeders with improvement in yield, while ensuring casting soundness without expensive and time consuming trial runs.
- The thick portion of the component was subjected to shrinkage porosity, pin holes, gas porosity etc. The root cause for the poor strength which leads to premature failure of the component.
- Proper design of gating system has immensely helped in achieving the directional solidification leading towards the feeder. Feeder was placed at solidifying region using Auto-CAST-X software.
- This approach has helped in minimizing the solidification related defects like pin holes, gas porosity and shrinkages, thereby providing a defect free casting. This reviews shows that simulation can be of great use in optimizing the feeder dimensions and increasing the feeding efficiency of the casting.

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