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A Review on Optimization of Gating System for Reducing Defect

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Abstract- *In the current global competitive environment there is a need for the casting units and foundries to develop the components in short lead time. Defect free castings with minimum production cost have become the need of foundry. The gating and riser system design plays an important role in the quality. Due to the lack of existing theoretical procedures the designing processes are normally carried on a trial-and-error basis. This paper review casting produced by foundry with internal shrinkage as a major defect was analyzed and identified that gating and risering system was improperly designed. The designed gating system reduced defect and increase yield. Finally, a more reasonable gating system was obtained by analysis of simulation results.*

Keywords: *Optimization; Casting design; Optimized casting design; Gating system; gating and riser design; Casting defects.*

1. Introduction

Two major considerations in the casting design are the quality of the final product and the yield of the casting. Production of sound & quality casting mainly depend on gating system. In Casting design the gating & riser system design has a direct influence on quality of cast component. Most engineering problems, casting design is done trial and error basis. Availability of modern software tool give designer an insight into the detail of fluid flow, heat transfer. Gating/riser system design is critical to improving casting quality[1]. Casting as a manufacturing process to make complex shapes of metal materials in mass production may experience many differ ent defects such as porosity, shrinkage, blowhole and incomplete filling. Improving the casting quality is important.

In casting there are two main stages, which are filling process and solidification process. In filling process consist of gating system composed of pouring cup, runner, sprue, and gate. Risers serve dual function, they compensate for solidification shrinkage and heat source so that they freeze last and promote directional solidification. Risers provide thermal gradients from a remote chilled area to the riser. Casting process design is important for production quality and efficiency. It is unavoidable that many different defects occur in casting process, such as porosity and incomplete filling. Casting quality is heavily dependent on the success of gating/riser system design, which currently is conducted mainly relied on technician"s experience. Therefore there is a need for the development of a computer-aided casting process design tool with CAD, simulation, and optimization functions to ensure the quality of casting. Gating system is referred as all channels by means of which molten metal is delivered to mould cavity. Clean metal implies preventing the entry of slag and inclusions into the mould cavity, and minimizing surface turbulence. Casting processes are widely used to produce metal parts in a very economical way, and to obtain complicated shapes with minimal machining for intended end use. A riser or a feeder is a reservoir to feed the molten metal to the casting to compensate the shrinkage during solidification. Riser is a passage made in the cope through which the molten metal rises after the mould is filled up. Risering in casting involves the determination of such size and location of risers which will enable the production of favorable temperature gradients for the directional solidification to take place effectively. Chills are achieving directional solidification. It is used preferably when the intricate shape of the casting does not allow placing of risers on all the thick sections or in which the large sections are so located that it is impossible to place risers over them. In such cases there will be different cooling rate for different section, giving rise to internal stresses causes cracks.Simulation is the process of imitating a real phenomenon using a set of mathematical equations implemented in a computer program. Using casting simulation visualization of mould filling, solidification and prediction of the location of internal defects such as shrinkage porosity, cold shuts and sand inclusions can be done. Moreover it is not only used for existing castings but also used in developing new castings without shop-floor trials.

2. Computer aided casting and design

Chokkalingam, Sidharthan[1] used a Pro-E software to build a casting model. They redesigned feeding system which is developed by Cast Calci in C using standard formulas available from the standard literature to do the calculation for the design of gating and risering system. Thoguluva Raghavan Vijayaram[2] used Boundary Element Method to get accurate result output and this is considered as an advanced technique by engineering scientists and engineering. Casting solidification simulation process is used to identify the 93 defective location in the casting from the generated time-temperature contour, which provide time-temperature data, temperature contours, hot spot location degree of rescalescene, latent heat of fusion and solidification time. Baha‟ I. Malaeb [3] use of CFD as a design tool for mould casting was demonstrated for a steel cast of an "ice cleat". The solidification model in FLUENT was used to model the solidification processes. The solidification throughout the mould was simulated using FLUENT for a number of differ ent design scenarios. Based on the simulation an optimum feeder placement was chosen. Furthermore the use of CFD to improve yield by minimizing feeder volume was also demonstrated.

S. M. Yoo, J. K. Choi [4] Z-Cast™ was used to simulate the fluid flow in a sand mold. The optimal processing parameters for the cooling were obtained from the analysis of fluid flow and solidification. Numerical simulations of mold filling and solidification were used to optimize the casting process. The simulations were used to predict the temperature distributions and solidification sequences in the casting to optimize the casting conditions.B. Ravi [5] used intelligent assistant for casting engineers (AutoCAST) and describes how it assists in designing, modeling, simulating, analyzing and improving cast products over electronic networks providing a glimpse of the way castings will be designed in future. intelligent software can automate casting design, modeling, simulation, analysis and suggestions for improvement while allowing the user ultimate control over all decisions.

3. Optimization approaches

1. Multi-Objective Evolutionary Algorithm (MOEA)

Kor, Chen, Hu[6] used An optimization method 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.

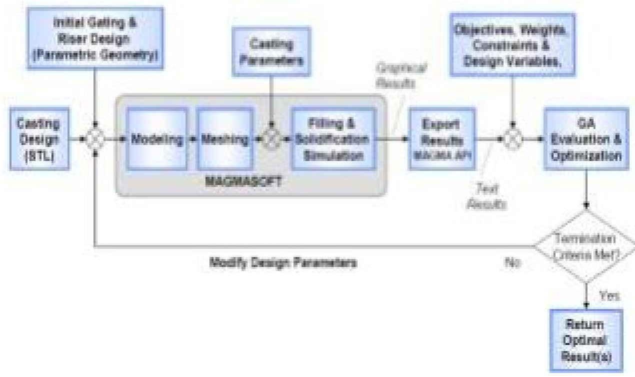

Fig.1. Schematic view of the CAD/CAE system[6].

2. Theory of Inventive Problem Solving (TRIZ)

Feng and Yi[7] Used the systematic method for identifying contradiction of casting process, which enhanced the conversion capability from specific problem to standard problem whilst improved the feasibility of TRIZ. It was observed that the integration of th e systematic method and solving tools of TRIZ increased the efficiency of casting process optimization.The Theory of Inventive Problem Solving (TRIZ).Optimization of casting process is divided into problem analysis and contradictions identification, an d problem solving and process optimization. It describe the casting defect, ascertainment the root cause, analyze and identify the factors in all levels, analyze the basic lowest level sub-problem using S-field model, and identify the contradictions. Define the problem. It is one of the most important innovation theories, which is suitable for complex multi-factors casting process problem.

3. Design of Experiments (DOE)

Senthilkumar.[8]used DOE as a tool to optimize the influencing factors. DOE is a series of ordered tests in which purposeful changes are made to input factors to identify the corresponding change in the output response variables. DOE is a statistical technique used to study the effect of the outcome of multiple variables simultaneously.Gating system is one of the influencing factor, the feeding system can be designed and dimensional once the optimal pouring temperature has been established, if the casting modulus is less than 0.3cm.However ensure that ingate does not froze off too early and thereby blocks the flow of feed metal from the pouring cup. It was concluded that, after employing the optimal factor values, the number of castings with pull-down defects were reduced. The approved percentage of castings had improved from 86.22% to 96.17%. Thus, by controlling pull-down defects, productivity was well improved.

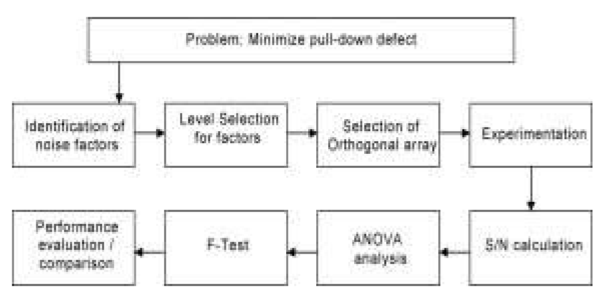

Fig.2 Factor optimization using Taguchi's DOE[8]

Sun, Hu, Chen[9] proposed an optimization technique for design of a casting based on the Taguchi method with multiple performance characteristics. As a result of this they found that the multiple performance characteristics such as shrinkage porosity, yielding in product can be simultaneously considered and improved through this optimization technique.

4. Feeder design rules

Designing a proper feeding system to account for the solidification shrinkage for a cast is guided by six main feeding rules [3]. These rules can be summarized as follows:

1. Heat transfer criterion: The feeder must solidify at the same time or later than the casting.

2. Mass transfer criterion: The feeder must contain sufficient liquid to meet the volume-contraction requirements of the casting.

3. The junction requirement: The junction between the feeder and the casting should not create a hot spot, i.e. be the last to solidify.

4. There must be a path to allow feed metal to reach feeding points.

5. There must be sufficient pressure differential requirement to cause the feed material to flow in the right direction.

6. There must be sufficient pressure at all points in the casting to suppress the formation of cavities.

Guided by these rules, the designer has to decide on the appropriate design parameters such as the position and the shape of the feeder for each particular case. These design decisions usually require skilled and experienced personnel and are iterative where different options are tried in the foundry and the valid one is chosen. This process gives priority to finding a sound design.

Tavakoli and Davami[10] have presented a method for automatic optimal feeder design in steel casting processes. Design of each feeder contains determination of the feeder-neck connection point on the casting surface, feeder shape optimization and feeder topology optimization.

5. Gating & Risering System

Gating system is to lead clean molten metal poured from ladle to the casting cavity, with less turbulence. Risers are used to compensate for liquid shrinkage and solidification shrinkage.[11]

1)No shrinkage defects: Risers have been designed and placed such that the whole casting is free from shrinkage.

2)Steady metal front rises up in the casting. There is no turbulence in the metal flow.

3)Initial dirty metal doesn‟t enter casting cavity neither does the slag.

4)Economy : Maximum yield. Weight of gating parts and risers is minimum.

5)Gating parts can be easily removed without affecting casting.

6)Pattern and gating parts fit on the match-plate with sufficient sand clearance.

7)Risering calls for a thermal analysis of the part. Gating parts calls for the fluid flow analysis.

6. Chills

Chills are metallic inserts placed in the mould at strategic places to extend the feeding distance. The ductile iron allows longer feeding distance than steel, so one can use less number of risers or avoid use of chills.[11]

1)Chill should be sufficiently thick so as not to fuse with the base metal.(0.6*T)

2)Chill should be clean, free from dents and dry. A rusty chill is highly prone to promote blow-holes near the contact area.

3)Chills in cope: It should be firmly locked in the mould

4)If smaller chills are used than the requirement, shrinkage porosities will be observed.

7. Conclusion

Casting simulation technology has become an essential tool for casting defect troubleshooting and optimization method. It im proves quality product without shop-floor trials.With the use of optimization techniques gating system of the casting are improve and increase the yield percentage of the casting. This would result reduction in cost and material saving. Many design rules, are developed over the years through experience and study. But For wide spread application, simulation programs must be easy to use, fast, and reliable. This can been achieved by integrating method design, solid modeling, simulation techniques. The Simulation software has proven its reliability and accuracy in predicting internal defects which help to reduced shop floor trials, and optimization using a single software program.

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