Yield Improvement of Castings using Computer Aided Simulation – A Case Study

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Abstract: Yield is the ability of a foundry to manufacture acceptable casting in an effective manner. Improving yield offers many commercial as well as financial benefits to the foundry. Along with direct cost control, high yield is also associated with better process control, and therefore improved cost control. By using computer simulation, an optimum gating system can be designed to improve the acceptability of the casting. Hence work has been done in this regard to analyse the defects of a casting and thus improve its acceptability.

Keywords: Yield, acceptability, gating system, computer simulation.

I. INTRODUCTION

The foundry sector is well recognized as one of the supporting industries for the machinery and assembling industry. But it suffers from poor quality and productivity due to the large number of process parameters, combined with lower penetration of manufacturing automation and shortage of skilled workers compared to other industries. Even in a completely controlled process, defects in casting are observed and hence casting process is also known as process of uncertainty which challenges explanation about the cause of casting defects. Buyers demand defect-free castings and strict delivery schedule, which foundries are finding it very difficult to meet. Casting defects result in increased unit cost. The defects need to be diagnosed correctly for appropriate remedial measures; otherwise new defects may be introduced. Unfortunately, this is not an easy task, since casting process involves complex interactions among various parameters and operations related to metal composition, methods design, moulding, melting, pouring, shake-out, fettling and machining. Casting defects analysis is the process of finding the root cause of occurrence of defects in the rejection of casting and taking necessary steps to reduce the defects and to improve the casting yield.

II. IMPORTANCE OF YIELD

Yield is usually defined as the total weight of good, saleable castings expressed as a percentage of the total weight of metallic of metallic materials melted to produce them. This can be represented by

$$\text{Yield} = \frac{Total\ weight\ of\ good\ castings}{Total\ weight\ of\ metal\ melted} \times 100 \qquad (1)$$

Actual yield of a foundry is always less than 100% because weight of the metal melted always exceeds that of the good quality castings dispatched. Most of the cost incurred to a foundry is the cost of energy required for melting of the metal. So even though the runner-risers of the castings and the defective castings can be melted again and the metal can be reused, improving yield helps reduces a foundry's overall operating cost significantly. Along with direct energy savings it offers, high yield is also associated with better process control, and therefore improved cost control. In addition it also offers direct savings to sand, non-recoverable metal, consumable items and effort. This is reflected in reduced cost together with a significant reduction in greenhouse gas emissions.

III. METHODOLOGY

The experimental work was carried out in a medium scale ferrous foundry producing grey and ductile iron castings. When the rejection analysis of the components was done it was found out that the rejection rate of most of the components was on the higher side. Thus, to increase the acceptability of the components, analysis of the reasons causing the rejections was necessary. After referring to various journal papers and research work, the analysis method suggested by Uday A. Dabade et al [2] which gives separate analysis routes for the defects caused due to sand/mould and defects caused due to solidification/methoding was adopted. A component named 'Brake Housing' which had rejection rate of 10.60% was selected for analysis. The main reason for the rejection was due to defects related to shrinkage and sand drop. Thus it was decided to use computer simulation for the analysis of the defects. The software used for simulation was ADSTEFAN (courtesy: BFPL, Belgaum).

Simulation is the process of imitating a real phenomenon using a set of mathematical equations implemented in a computer program. In casting simulation the mould filling and solidification analysis is done by using an algorithm or program based on finite volume method, to identify the hot spots and hence defects like shrinkage porosities, hot tears, cracks, etc. The simulation programs are based on finite element analysis of 3D models of castings and involve sophisticated functions for user interface, computation and display. The casting model (with feeders and gates) has to be created using a solid modelling system and imported into the simulation program. Ravi[1] has suggested casting simulation and optimization methodology as shown in Figure 1.

STEP 1: Data Gathering	Part model, Material, Process parameters, Methods design, Existing defects
STEP 2: Methods Design	Parting line, Cores, Feeders, Feedaids, Gating system, mold cavity layout
STEP 3: Simulation	Model import, Mesh generation, Material and process, Computation, Visualisation
STEP 4: Optimization	Modify design, Simulation, Check quality, Check yield, Check cost
STEP 5: Project Closure	Methods report, Analysis report, Images slides, Compare results, Archive project

Fig. 1: Casting simulation-optimization methodology [1]

3.1 Data Collection

In this stage,data regarding the existing defects, process parameters, materials, methods design was collected and analysedfor selected casting.A total of 162 units of 'Brake Housing' was produced out of which 14 were rejected with a rejection rate of 10.60%(the rejection rate is calculated based on the total weight of the metal poured and not on the number of units). The material used for brake housing is ductile cast iron and the casting process used is carbon dioxide casting process in which sodium silicate is used as a binder. The main causes of rejection of this component were Blow Hole, Sand Drop and Shrinkage defects which were visible after the machining of the component.

Image of brake housing with defect is shown in Figure 2 and the solid model of the existing gating design of the brake housing is shown in Figure 3.

Fig. 2: Casting with Shrinkage Cavities and Sand Drop Defect

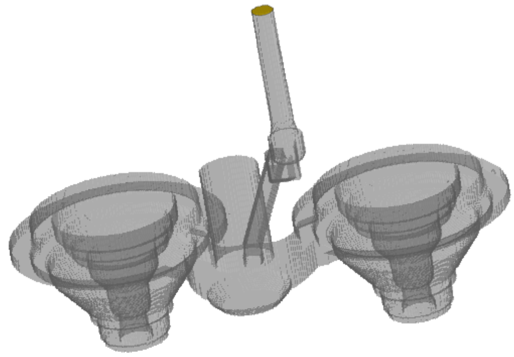

Fig. 3: Solid Model of the existing gating system of the Brake Housing gating system (two cavity mould).

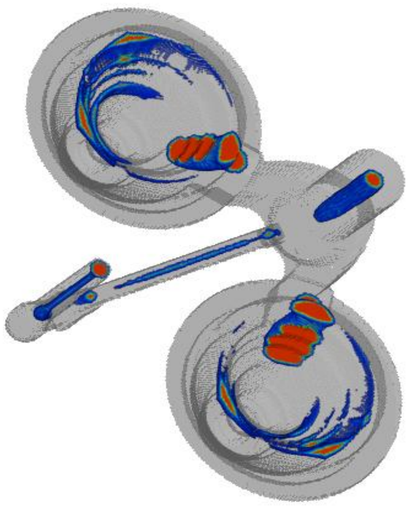

Fig. 4: Shrinkage cavities for the existing gating system

3.2 Simulation Trials

In the existing system, a central hot riser was used to feed both the cavities of the two cavity mould during solidification. The pouring was done through a sprue which was connected to the riser by means of a runner bar. The riser was insufficient to feed the casting during the solidification which resulted in the shrinkage cavities inside the casting as shown in Figure 4.

A new gating system was designed (for two mould cavity) using theoretical formulae used forgating and risering system design. Feeder was designedby modulus method. In this two clod risers were placed on top of each cavity and the pouring was done through a central sprue as shown in Figure 5. Even in this design there was some shrinkage cavities were observed just beneath the risers as seen in Figure 6.

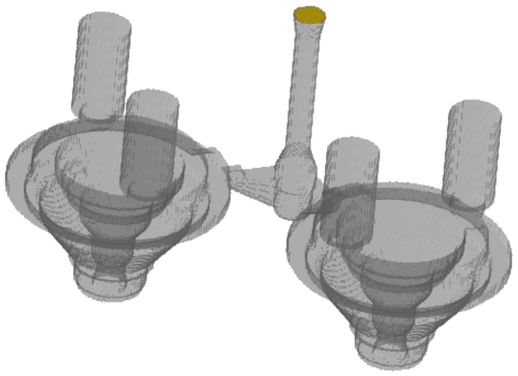

Fig. 5: Solid Model of second trial.

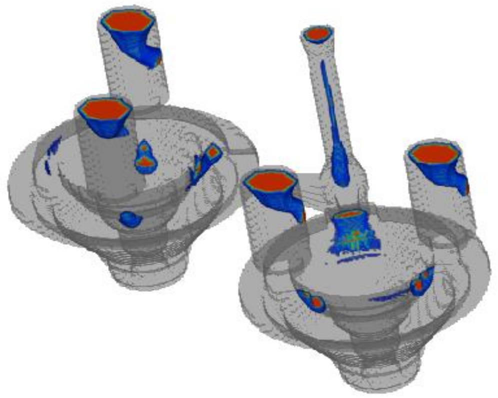

Fig. 6: Shrinkage Cavities for the second trial.

In the next trial the casting was inverted and a bigger riser of higher modulus was placed on the new top of each cavity as shown in Figure 7. The bigger riser promoted the directional solidification of the casting and sufficient feeding was also accomplished. This design showed no shrinkage cavities in the casting, the shrinkage cavities were observed in the riser and also there was no burnout of the sand which was causing the sand drop defect. Figure 8 shows the shrinkage cavities present in the riser, there were no shrinkage cavities observed in the casting.

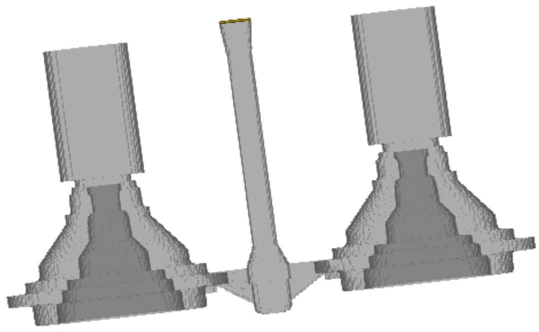

Fig. 7: Solid Model for the gating system of the optimum iteration.

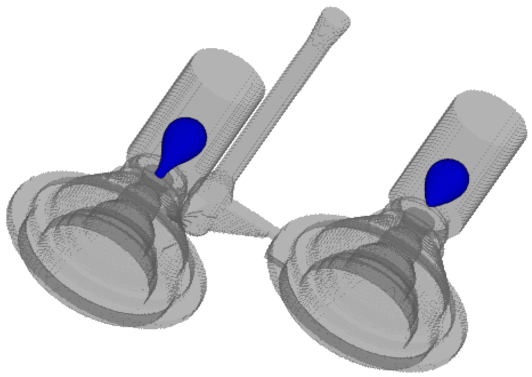

Fig. 8: Shrinkage cavities for the third trial

This gating system was then tried out practically and there were no defects observed in the initial trials. Then this system was adopted for regular production and the rejection rate was observed to be around 1.5% for over 500 castings.

IV. CONCLUSION

- Computer trials were successfully carried out to reduce the rejection rate of the component
- The box weight of the casting was found to be increased to 44.2kg. The box weight for the previous system being 39.8kg. Thus, the box yield was reduced form 75.37% to 67.82%.
- Only 9 of the 592 components manufactured by implementing the new system were rejected. Thus the rejection rate of the component was reduced from 10.60% to 1.52%.
- Thus by carrying out trials with the help of computer simulation, a lot of metal, time, labour and money were saved.

REFERENCES

[1] B. Ravi, 2010, “Casting Simulation-Best Practices”, Indian FoundryCongress, Ahmadabad.

[2] Uday A. Dabade,Rahul C. Bhedasgaonkar, “Casting Defect Analysis using Design of Experiments (DoE) and Computer Aided Casting Simulation Technique”, Procedia Forty sixth CIRP Conference on Manufacturing Systems 2013, pg. 616 – 621.

[3] K. Siekański, S. Borkowski, “Analysis of Foundry Defects and Preventive Activities for Quality Improvement of Castings”, METALURGIJA 42 (2003) 1, pg. 57-59.

[4] Kenji Ogawa, Shinya Kanou, Shigeru Kashihara, “Fewer Sand Inclusion Defects by CAE”, Komatsu Technical Report, VOL. 52 NO.158, 2006.

[5] Lakshmanan Singaram, “Improving Quality of Sand Casting Using Taguchi Method and ANN Analysis”, International Journal on design and Manufacturing Technology, Vol. 4, No. 1, January 2010, pg 1-5.

[6] B.R. Jadhav, Santosh J Jadhav, “Investigation and Analysis of Cold Shut Casting Defect and Defect Reduction by Using 7 Quality Control Tools”, International Journal of Advanced Engineering Research and Studies, July-Sept., 2013, pg. 28-30.

[7] B. Borowiecki,O. Borowiecka, E. Szkodzińka, ”Casting Defects Analysis by the Pareto Method”, Archives of Foundry Engineering, Vol. 11, Special issue 3, 2011, Pg. 33-36.

[8] Peter Beeley, “Foundry Technology”, Butterworth-Heinemann, second edition, 2001.

[9] ASM Metals Hand Book,“Casting”, ASM International, Volume 15,1998.

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