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Reducing rejection rate of castings using Simulation Model

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Abstract

Rejection rate is one of the major issues in Indian foundry. Foundries try to reduce rejection by experimenting with process parameters or modifying method and tooling design which reduces the quality of castings and increase cost of production. By replacing the existing trial and error method with computer simulation foundries can reduce the rejection rate from 8.5 to 3.5 %. The paper titled “Reducing rejection rate of castings using Simulation Model” is aimed at reducing rejection rate of castings in an Indian foundry. The overall goal of the project proposed here in is to reduce the rejection rate using simulation model in foundries. In this paper a case study on a cylinder clamp casting of Milacron product, which is having high rejection rate in an Indian foundry is taken and the defects of casting are solved using the proposed simulation model with Magma 5 software and the effective solutions for reducing rejection rate for the product is also given.

Keywords: Casting defects, simulation model for casting, quality tools, casting simulation, Foundry process, rejection control of castings.

1.INTRODUCTION

Due to the high rejection rate the production in foundry and customer confidence is lost. We proposed to use simulation techniques to predetermine the defects and find appropriate solutions for reducing rejection rate of castings before its trial production in foundry. The main objective of this research is to reduce the rejection rate of castings in Indian Foundries. Casting simulation is used for reducing rejection rate with the help of simulation software Magma5. Firstly the rejection rate of castings of past five years is collected from quality control reports of an Indian foundry. Then the major defects for casting which leads to rejection is identified with the help of quality tools such as Defective factor check sheet, Pareto analysis and Cause and Effect diagram. A simulation model is created to optimize the casting process and the major defects are identified before the trial production in foundry and the solution for particular defects are given to reduce the rejection of castings. The study provides a better understanding of various production processes, performance and entire activities of various foundries. It provides a great opportunity to analyze the drawbacks of foundry and reasons behind the negligence for Indian casting industry due to high rejection rate.

2.LITERATURE REVIEW

To reduce the rejection rate of castings, a detailed literature review was carried out for identifying the major defects which leads to rejection of castings and to solve these defects using simulation model using advanced software is done effectively. Previous literature has shown that there are few research studies related to rejection control of castings in foundry using different simulation models and also some research papers which gives solutions to solve the major defects during gating and feeding process in castings.

Classification of casting defects in aluminium die castings and Die-casting defects which are grouped according to their source during which these defects can be detected [7]. This classification helps the die caster in the stage of identification of the defects, on the other side; it makes him easily aware of problems so that the proper corrective actions can be taken.

Casting defect analysis which has been carried out using techniques like cause-effect diagrams, design of experiments, if-then rules (expert systems), and artificial neural networks [8].Most of this work is focused on finding process-related causes for individual defects, and optimizing the parameter values to reduce the. The defects have been classified in terms of their appearance, size, location, consistency, and discovery stage and inspection method. This helps in correct identification of the defects. For defect analysis, the possible causes are grouped into design, material and process defects parameters also to accomplish defect analysis taking benefits of both approaches; new hybrid approach for defect analysis is proposed.

Various forging defects that occur in a forging industry that causes high rejection rates in the components and this paper describes the remedial measures that can reduce these defects in the hot forging[9].He describes the remedial actions that to be done in order to reduce the rejection rates. The remedial actions includes the proper use of anti scale coating, venting process to prevent the under filling, the simulation software for determining the material flow, proper lubricant instead of furnace oil.

A collaborative system for achieving perfect castings high quality with frugality by integrating part, tooling, methods and process optimization, and providing feedback loops to part design[10].Each subsequent phase provides more information and feedback regarding part quality and cost to the designer, allowing design improvements for manufacturability without affecting functionality. A secure web-based project management system enables rapid and seamless collaboration between casting lifecycle engineers.

The timely implementation of modified techniques based on the quality control research is a must to avoid defects in the products[11]. For this he initially collected information of rejection of some components which leads to rejection and then analysis these with Pareto chart and giving proper remedies of to control rejection.

3.RESEARCH METHODOLOGY

The methodology begins with the collection of rejection rate of various castings for past five years from the quality control reports of an Indian foundry. From this the casting having the highest rejection rate and the major causes of rejection is identified using quality tools such as defective factor check sheet, Pareto analysis and Cause and effect diagram. The casting with highest rejection rate is simulated with Magma 5 software and its 3D modelling is done in PRO/E software. A model is also created for optimization of castings process through simulation and the major causes are predicted and its solutions are given.

The methodology to carry out the project is given by a flow diagram shown in Fig 1.

4. DATA COLLECTION AND ANALYSIS

Primary data includes the rejection rate of castings for the past few years and its major problem and causes which are obtained from Quality control reports and Rejection reports of an Indian Foundry. Secondary data are obtained from journals,literature survey and websites.

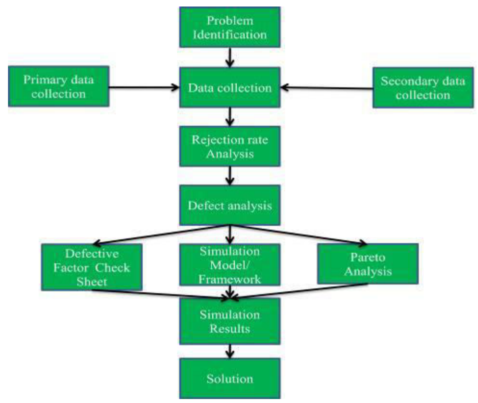

Fig 1: Research Methodology Flow diagram

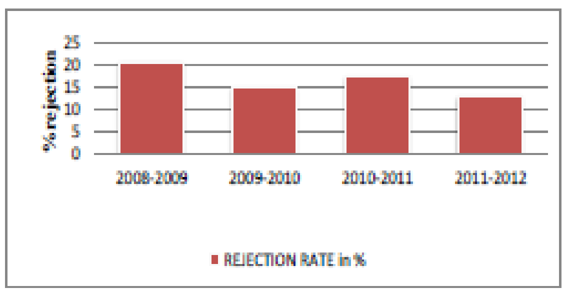

Fig.2: Rejection rate for past five years in Autokast.

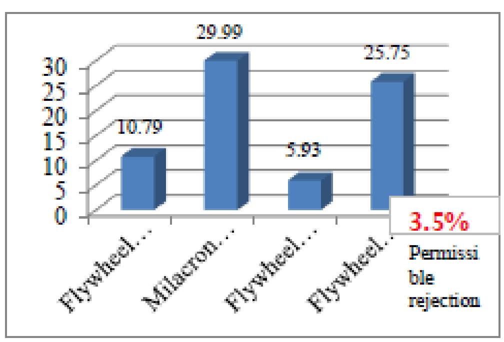

Fig.3: Rejection rate compared to Permissible rejection as per ISO standard

Fig:2 Shows the rejection analysis of an Indian foundry which is having an average rejection of around 19.5 percentages and the permissible customer rejection as per ISO standard is 3.5 percentage. In fig:3 different castings produced in that particular Indian foundry for the last six months was chosen and it is clear that the casting named Milacron cylinder clamp is having the highest rejection in last six months. So we found the reasons or major causes of rejection behind the Milacron castings. From the quality control reports of Autokast we find out the major causes of rejection using defective factor check sheet, Pareto analysis and Cause and effect diagram which is shown below.

TABLE 1: DEFECTIVE FACTOR CHECK SHEET FOR MILACRON PRODUCT

Rejection Reasons/defective	Mean occurrences of Defects
Sand Drop	22
Scab	3
Mould Breakage	31
Sand Inclusion	15
Cold Joint	61
Broken	7
Surface Defect	2
Other Reasons	14

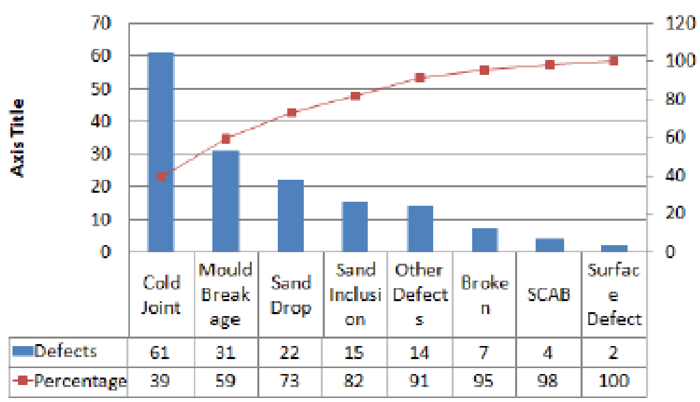

Fig:4 Patreto Chart

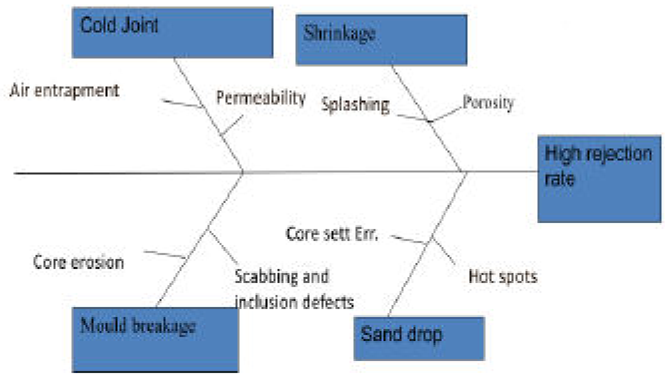

Fig 5. Fish -bone diagram: High rejection rate

In Table:1 defective factor check is drawn showing the major defects of Milacron product and its mean occurrences and from this result a Pareto chart in Fig:4 showing critical effects of major defects in percentage and its causes in decreasing order is plotted and the cumulative percentage for defects and causes of defects are identified.From the above quality tools the cause and Effect Diagram of Milacron Product in Fig:5 is drawn and identify the major causes and its effects which causes high rejection rate of this casting.

5. SIMULATION MODEL

A simulation model is proposed for reducing defects of casting and this model is a "Design for Manufacturability model" which has been proposed to show the reason why these manufacturing process are ignored in the design process and the lack of focus of designers on the manufacturing process can be eliminated by this model. A feedback loop is provided to Design Engineer in each and every phase of this model and this bring an integration in casting process between the foundry engineers and design engineers to reduce the rejection rate and improve quality by optimization in four phases of framework. The four Phases of the model are Model Design Phase (Design Engineers), Pattern Making Phase (Skilled craft men), Method Designing Phase (Metallurgical & Design Engineers), Process Planning Phase (Metallurgical &Production Engineer).

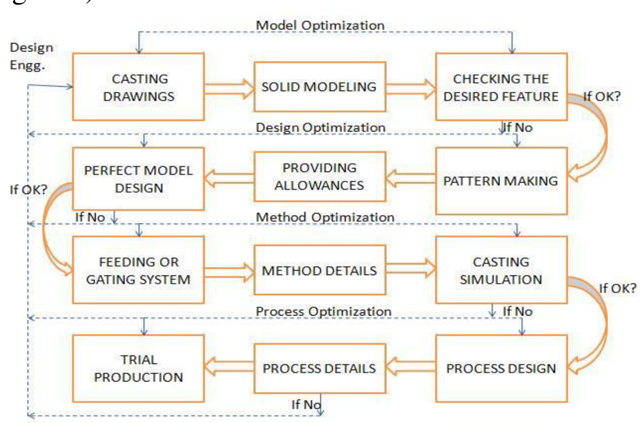

Fig:6 Simulation Model

From analysis result it is clear that Milacron Cylinder Clamp is having a high rejection rate of 29.99% mainly due to integrity factors. So the casting process of this product is simulated and the solution for reducing rejection rate can be predicted with Magma 5 software. 3D modeling of this product is done in PRO/E Wildfire 5 software. Casting simulation is used to design and optimize the casting process. In casting process normally the part design and specifications are already fixed. Simulation process are mainly applicable in mould filling, solidification, mechanical properties and stress calculations.

An advanced casting simulation software Magma 5 is used for casting process. Magma 5 is designed to predict total casting quality by simulating mould filling, solidification and cooling and stresses/strains as well as microstructure formation and property distributions in casting manufacturing processes. Magma 5 can be used for all cast materials, ranging from gray iron, sand and die cast aluminium, to large steel castings. Magma 5 is also applicable to all casting processes, to optimize tooling designs, minimize cycle times and predict defect formation all before production.

6.SIMULATION RESULTS AND SOLUTIONS

Optimum Temperature for this product during filing is 1340-1360ºC. The areas having red color is due to loss of superheat and the temp is reduced to 1230ºC. Defect in this reddish region is splashing or back pressure. To sole this defect sleeve material is provided thereby increasing the efficiency of Runner and Raiser.

The areas having white color in Fig: 7 are having more temp than 1360ºC which leads to Sand inclusion defects and it can be solved by providing Chill material.

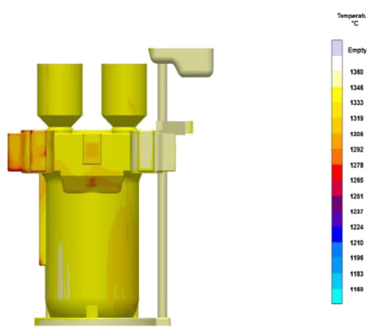

Fig:7 Filling temperature result

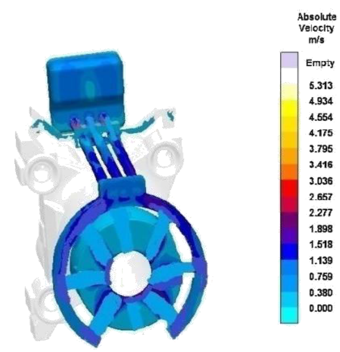

Fig: 10 Solution for high velocity in ingates

Filling velocity result shown in Fig: 8 can predict the area with high velocity. Optimum velocity of this product is 2.25m/sec. Liquid metal releasing more than 3m/sec leads to core erosion and splashing. These defects can convert in to Inclusion defect also. CO_2 process mould can withstand liquid metal velocity of 2.25m/sec. All bottom ingates in Fig: 9 releasing high velocity liquid metal more than 3m/sec, leads to mould erosion and can convert into inclusion defects

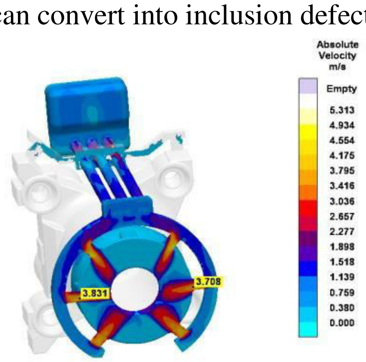

Fig: 9 Fluid Filling

The defect in this case can be solved by modifying the ingates to 8 numbers (as shown in Fig.10) from present 6 which is shown in Fig: 8.

Optimum mould erosion should be null which is shown in light blue color. The areas showing red color is having mould erosion of 2.40%. Due to high velocity liquid metal at ingate cross section sand gets eroded it may lead to inclusion defects. To solve this defect, ceramic tubes can be used as ingates which has a heat withstanding capacity of 2500°C.

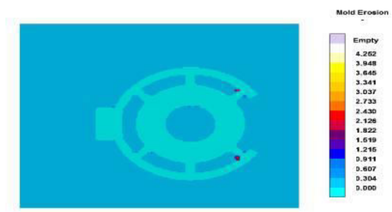

Fig: 11 Mold Erosion Result

Optimum Air entrapment for the product should be beyond 10%. Result indicates the possibility of blow hole defect which is shown in navy-blue color In Fig:12 having 13% air entrapment. This defect can be overcome by providing holes in mould for escaping gasses in those particular areas.

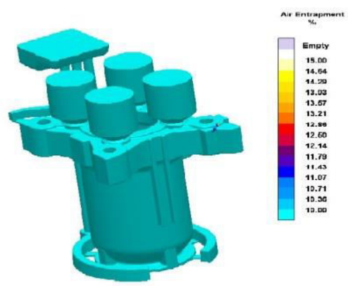

Fig: 12 Filling –Air Entrapment Result

Fraction liquid result in Fig:13 indicates the directional solidification. With this result we can predict feeder performance and last solidifying areas. In result the isolated regions may lead to micro/macro shrinkage porosity

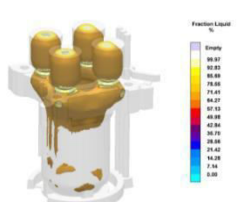

Fig: 13 Fraction - Liquid result

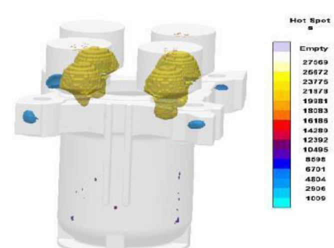

Fig: 14 Solidification – Hotspots result

In Fig: 13 isolated areas are noticed and it may lead to shrinkage porosity defect. Liquid in thinner section has the chance to solidify earlier than thicker section. The solution for this defect is to provide chill which maintain equal solidification in those areas. Areas having blue color in Fig: 14 is due to hot spot defect having a temperature above 1360 ^{0}C. Due to high pouring temperature and improper ramming hot spots are formed which leads to the defect shrinkage porosity. Shrinkage defects forms rough voids and is due to entrapped gasses.Solution for this defect is to provide proper cooling and heating in certain areas to maintain uniform cooling. Arrange proper ramming and clamping of mould boxes can also eliminate this defect.

Optimum porosity for product is null percentage and is shown in light blue color in Fig:15. Yellowish red color area having porosity defects of 40%. It results from entrapped gasses and also from sand drop. Porosity occurs sometimes due to improper chemical composition Solution for this defect is to provide proper vent holes for gasses to escape and keeping right chemical composition Also by adding certain metallic elements to get reaction with these gasses is also effective.

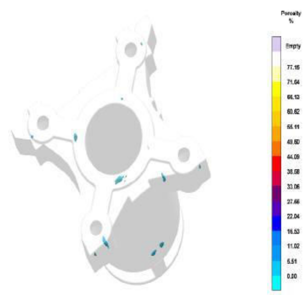

Fig: 15 Solidification – Porosity Result

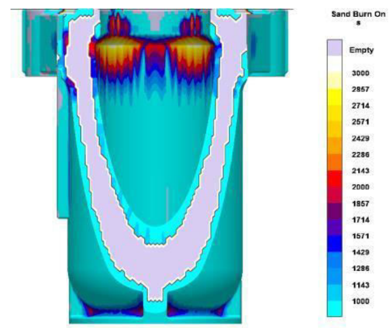

Fig: 16 Solidification – Sand fusion Result

Thinner areas when prone to temp above 1340ºC leads to sand penetration defect. Here areas having navy blue color is having defect. Temperature in that region is 1450ºC. It occurs usually in thinner sections and in areas where the ingates are small. More heat is formed in that region and sand gets eroded and cause the sand penetration defect. Sand fusion defect is eliminated by using Zircon sand in thin ingates which can withstand high temperature.

The tensile strength in each section Shown in Fig: 17 can be checked. Here the minimum tensile strength is found to be 400-420N/mm²

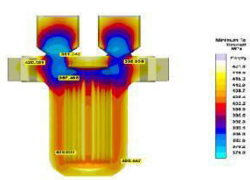

Fig: 17 Mechanical properties results.

7. CONCLUSION

This paper has introduced a new Simulation model or framework to reduce the rejection rate in foundry from 15% to merely 7%. From the analysis report of an Indian foundry the Milacron cylinder clamp product which is having high rejection rate due to major defects such as sand inclusion,cold shuts, shrinkage, mold breakage etc are solved using simulation software Magma5 before its trial production. The rejection rate of this product is reduced by proper optimization of the process and through strategic solution from the simulation techniques. The proposed model coupled with process control has the potential to achieve null defect castings at the least cost. This work gives up many challenges that need a new generation of researchers to come forward and help the mother of all industries.

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