ADVANCED TECHNIQUES IN CASTING DEFECTS AND REJECTION ANALYSIS: A STUDY IN AN INDUSTRY

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ABSTRACT

Casting process is the most widely used process in manufacturing industries especially in automotive products. Production of casting involves various processes like pattern making, molding, and core making and melting. It is very difficult to produce defect free castings. A defect may be the result of a single cause or a combination of causes. The castings may have one or more defects. Foundries are still using trial and error methods to solve quality problems. There are benefits of using a more disciplined approach to define, identify and determine the root cause of the defect which is an expensive and error-prone process. This project is about new devolvement for identification of defects for 4R cylinder block which is presently having a 40% or more percent rejection in Kirloskar ferrous industrial ltd, Solapur. This project also presents a methodology in rejection level percent by using scientific study on casting defects. Various casting quality improvement techniques such as; Product Process Search analysis (PPS) Inspection method, Design of Experiment (DOE), and by using a Casting simulation software and by finding out the cause-effect diagram. This project presents a review on literature of different methods adopted by many foundries to reduce the percent of rejection. A new approach is proposed which may be helpful for foundries for controlling and reducing the defects.

KEYWORDS:

OBJECTIVE OF THE RESEARCH

The main objective to carry out this research work is to minimize rejection percentage in 4R cylinder block casting, there are varieties of problems related to product quality in industries in this project work different casting defects are studied out by Advance techniques, this study will definitely be helpful in improving the productivity and yield of the casting. Rejections of the casting on the basis of the casting defect should be as minimized and the entire above project is heading in the same direction.

INTRODUCTION

Casting is a process which carries risk of failure occurrence during all the process of accomplishment of the finished product. Hence necessary action should be taken while manufacturing of cast product so that defect free parts are obtained. Mostly casting defects are concerned with process parameters. Hence one has to control the process parameter to achieve zero defect parts. For controlling process parameter one must have

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knowledge about effect of process parameter on casting and their influence on defect. To obtain this all knowledge about casting defect, their causes, and defect remedies one has to be analyze casting defects. Casting defect analysis is the process of finding root causes of occurrence of defects in the rejection of casting and taking necessary step to reduce the defects and to improve the casting yield. In this review paper an attempt has been made to provide all casting related defect with their causes and remedies. During the process of casting, there is always a chance where defect will occur. Minor defect can be adjusted easily but high rejected rates could lead to significant change at high cost. Therefore it is essential for die caster to have knowledge on the type of defect and be able to identify the exact root cause, and their remedies.

CASTING DEFECTS CAN BE CLASSIFIED AS FOLLOWS-

1. Filling related defect
2. Shape related defect
3. Thermal defect
4. Defect by appearance

These defects are explained as follows.

- **Filling related defects**

Blowhole: - Blowhole is a kind of cavities defect, which is also divided into pinhole and subsurface blowhole. Pinhole is very tiny hole. Subsurface blowhole only can be seen after machining. Gases entrapped by solidifying metal on the surface of the casting, which results in a rounded or oval blowhole as a cavity. Frequently associated with slags or oxides The defects are nearly always located in the cope part of the mould in poorly vented pockets and undercuts.

Sand burning: - Burning-on defect is also called as sand burning, which includes chemical burn-on, and metal penetration. Thin sand crusts firmly adhering to the casting. The defect occurs to a greater extent in the case of thick-walled castings and at high temperatures. The high temperature to which the sand is subjected causes sintering of the bentonite and silicate components. In addition, the always present iron oxides combine with the low-melting-point silicates to form iron silicates, thereby further reducing the sinter point of the sand. Sintering and melting of the impurities in the moulding sand enable the molten iron to penetrate even faster, these layers then frequently and firmly adhering to the casting surface

Sand inclusion: - Sand inclusion and slag inclusion are also called as scab or blacking scab. They are inclusion defects. Looks like there is slag inside of metal castings. Irregularly formed sand inclusions, close to the casting surface, combined with metallic protuberances at other points. Sand inclusion is one of the most frequent causes of casting rejection. It is often difficult to diagnose, as these defects generally occur at widely varying positions and are therefore very difficult to attribute to a local cause. Areas of sand are often torn away by the metal stream and then float to the surface of the casting because they cannot be wetted by the molten metal. Sand inclusions frequently appear in association with CO blowholes and slag particles. Sand inclusions can also be trapped under the casting surface in combination with metal oxides and slag's, and only become visible during machining. If a loose section of sand is washed away from one part of the mould, metallic protuberances will occur here and have to be removed.

Cold lap or cold shut: - Cold lap or also called as cold shut. It is a crack with round edges. Cold lap is because of low melting temperature or poor gating system. When the metal is unable to fill the mould cavity completely and thus leaving unfilled portion called misrun. A cold shunt is called when two metal streams do not fuse together properly.

Misrun: - Misrun defect is a kind of incomplete casting defect, which causes the casting uncompleted. The edge of defect is round and smooth. When the metal is unable to fill the mould cavity completely and thus leaving unfilled portion called misrun. A cold shunt is called when two metal streams do not fuse together properly.

Gas porosity: - The gas can be from trapped air, hydrogen dissolved in aluminum alloys, moisture from water based die lubricants or steam from cracked cooling lines. Air is present in the cavity before the shot. It can easily be trapped as the metal starts to fill the cavity. The air is then compressed as more and more metal streams into the cavity and the pressure rises. When the cavity is full it becomes dispersed as small spheres of high pressure air. The swirling flow can cause them to become elongated.

- **Shape defects**

Mismatch defect: - Mismatch in mold defect is because of the shifting molding flashes. It will cause the dislocation at the parting line.

Distortion or warp: - Warped Casting—Distortion due to warp age is known as warp defect.

Flash defect: - Flash can be described as any unwanted, excess metal which comes out of the die attached to the cavity or runner. Typically it forms a thin sheet of metal at the parting faces. There are a number of different causes of flash and the amount and severity can vary from a minor inconvenience to a major quality issue. At the very least, flash is waste material, which mainly turns into dross when re-melted, and therefore is a hidden cost to the business.

- **Thermal defects**

Cracks or tears: - Cracks can appear in die castings from a number of causes. Some cracks are very obvious and can easily be seen with the naked eye. Other cracks are very difficult to see without magnification.

Shrinkage: - Shrinkage defects occur when feed metal is not available to compensate for shrinkage as the metal solidifies. Shrinkage defects can be split into two different types: open shrinkage defects and closed shrinkage defects. Open shrinkage defects are open to the atmosphere, therefore as the shrinkage cavity forms air compensates. There are two types of open air defects: pipes and caved surfaces. Pipes form at the surface of the casting and burrow into the casting, while caved surfaces are shallow cavities that form across the surface of the casting. Closed shrinkage defects, also known as shrinkage porosity, are defects that form within the casting. Isolated pools of liquid form inside solidified metal, which are called hot spots. The shrinkage defect usually forms at the top of the hot spots. They require a nucleation point, so impurities and dissolved gas can induce closed shrinkage defects. The defects are broken up into macro porosity and micro porosity (or micro shrinkage), where macro porosity can be seen by the naked eye and micro porosity cannot

Sink mark and void: - Sink marks and voids both result from localized shrinkage of the material at thick sections without sufficient compensation. Sink marks appear as depressions on the surface of a molded part. These depressions are typically very small; however they are often quite visible, because they reflect light in different directions to the part. The visibility of sink marks is a function of the color of the part as well as its surface texture so depth is only one criterion. Although sink marks do not affect part strength or function, they are perceived to be severe quality defects. Voids are holes enclosed inside a part. These can be a single hole or a group of smaller holes. Voids are caused when the outer skin of the part is stiff enough to resist the shrinkage forces thus preventing a surface depression. Instead, the material core will shrink, creating voids inside the part. Voids may have severe impact on the structural performance of the part. moldings sink mark and void.

- **Defects by Appearance**

Metallic projection Joint flash or fins. : - Flat projection of irregular thickness, often with lacy edges, perpendicular to one of the faces of the casting. It occurs along the joint or parting line of the mold, at a core print, or wherever two elements of the mold intersect.

Cavities: - Blowholes, pinholes, Smooth-walled cavities, essentially spherical, often not contacting the external casting surface (Blowholes). The defect can appear in all regions of the casting.

Discontinuities: - Hot cracking. A crack often scarcely visible because the casting in general has not separated into fragments. The fracture surfaces may be discolored because of oxidation. The design of the casting is such that the crack would not be expected to result from constraints during cooling.

Incomplete casting: - Poured short. The upper portion of the casting is missing. The edges adjacent to the missing section are slightly rounded; all other contours conform to the pattern. The spree, risers and lateral vents are filled only to the same height above the parting line, as is the casting.

Incorrect dimension or shape: - Distorted casting. Inadequate thickness, extending over large areas of the cope or drag surfaces at the time the mold is rammed.

Defective surface Flow marks. : - On the surfaces of otherwise sound castings, the defect appears as lines which trace the flow of the streams of liquid metal

Rat Tail and Buckles: - Rat tails and buckles are caused by the expansion of a thin outer layer of moulding sand on the surface of the mould cavity due to metal heat.

LITERATURE SURVEY

1) C. M. Choudhari, B. E. Narkhede, S. K. Mahajan have studied The casting defects can be minimized by an intelligent methoding and simulation using casting software. The software simulates the way casting engineers decides the casting process, parting line, cores, mould box, feeders, gating system and mould layout, and analyzes each decision to suggest how the design could be modified to improve quality as well as reduce tooling and manufacturing costs. Hence casting solidification simulation enables predicting and preventing potential problems before freezing the product design, determining 'good first' methodology solutions to achieve high yield at the desired quality level, and evolving optimal process plans compatible with both product requirements and foundry capability. The methodology involves four major decisions: (1) orientation and parting line, (2) core print design, (3) feeder design, and (4) gating design. The objective of this research work is to carryout numerical simulation of casting solidification with experimental trials to minimize above mentioned defects. Casting simulation and analysis has been studied by many researchers and their achievement and limitations are taken into account while solving the case study. The solidification phenomena in sand mould for thermal stress using finite element analysis has been carried out and author has discussed about the effect of solidification on stress formation in casting where the experimental data was available [4]. The defects formation during solidification of Al alloy using ABAQUS has been studied and showed that most of the defects formed where the metal solidified last [5]. Thermal history of the sand casting process for mould filling time using FORTRAN has been investigated. This study has shown that the lastly solidifying area is near the junction [6]. Optimum riser design and its location will ensure removal of hot spot from the casting. Here, riser having higher value of the modulus has been designed so that it should have higher solidification time compared to casting [7]. Computer-aided casting design and simulation provides much better and faster insight for optimizing the feeder design of castings [8]. The application of computer aided methoding, and casting simulation in foundries can minimize the bottlenecks and non-value added time in casting development, as it reduces the number of trial casting required on the shop floor [9].

2) Prachi K. Tawele, Laukik P. Raut-, the defect of casting i.e. warpage can be reduced. These will helpful to quality control department of casting industries for analysis of casting defects. Also the casting simulation technology has now days become a beneficial powerful tool for casting defect troubleshot. This will reduce the lead time for the sample casting; improved productivity. In general, warpage can be eliminated by iteratively designing (gating) system and by referring methods which helps in analysis of casting defects may minimizes the rejection of casting

3) P. Shailesh, S.Sundarrajan and M.Komaraiah studied the centrifugal casing technique for Al-Si alloy and optimized its process parameters using Taguchi's method of Design of Experiments. It was observed that the mechanical properties of the components such as density and yield strength were enhanced by refining the process using Taguchi Design of Experiments (DOE) model. The results indicated that the reducing the pouring temperature and increasing the speed of the die leads to improved mechanical properties of the casted components. finite difference-based casting process simulation software and it is quantified using mathematical formulae. CAD has been used for construction of three-dimensional model
of the shrinkage defect. Shrinkage characteristic has also been quantified through experimental validation studies and compared well with casting process simulation. Shrinkage characteristic study and control is essential for producing defect-free castings

4) T.R.Vijayaram, S.Sulaiman, A.M.S.Hamouda, and M.H.M.Ahmad (Research Paper) Metal casting industries are actively involved to reduce scrap rejection and rework during manufacturing process of the components, to achieve this, the production concerns must follow the quality control procedures correctly and perfectly without any negligence. Timely implementation of the modified techniques based on the quality control research is a must to avoid defects in the products. In this review paper, some of the solutions and quality control aspects are explained in a simplified manner to eliminate the unawareness of the foundry industrial personnel who work in the casting manufacturing quality control departments. This review paper provides very valuable information to the young manufacturing and mechanical engineers who have interest to start their carrier in the manufacturing concerns of medium and large scale foundries. Besides, statistical quality control (SQC) is also highlighted to understand its recent application and techniques adopted in the developing metallurgical engineering foundries.

5) Dr.M.Arasu (Head, Department of Foundry Technology, PSG Polytechnic College) In the manufacturing sector, metal casting industry is one of the basic, principal and most important industries. In the present global scenario of recession and high competitiveness among the foundry industry, cost effectiveness has a crucial role to play in determining the edge of one over the other and the industry as a whole. Cost effectiveness does not mean a strategy that saves money and just because a strategy saves money doesn't meant that it is cost-effective. The casting process is hindered by the occurrence of varies defects. High casting reject levels, both internal and customer returns have a considerable adverse effect on productivity, delivery performance, customer satisfaction and employee morale in addition excessive rejection reduces yield, wastes valuable raw materials and involves management time in problem solving.
All foundry process generates a certain level of rejection that is closely related to the type of casting, the process used and the equipments available. However, in most foundries a substantial proportion of rejection result from lake of shop-floor supervision and technical control, and the use of poorly maintained and inadequate equipment. The rejected casting can only be re-melted and the value addition made during varies processed such as, melting, moulding, fettling and heat treatment, etc is lost irrecoverably. Keeping rejection to a bare minimum is essential to improve the yield and increase the effective capacity of the foundry; Most of the foundries have no precise knowledge of the main cause of rejection because they fail to maintain a satisfactory quality control system. There is a need for an organized system of collecting information on the process parameters relating to the potential casting defects. Also, there is need for developing a database of solutions for eliminating undesirable casting artifacts. Internal and external failure costs contribute to over 70% of the total quality cost in foundries.

6) Guo-fa MI, Xiand-yu, Kuang-fei WANG, Heng-Zhi FU The numerical simulation technique was applied to the casting process of a valve type part. The mold filling and solidification stages of the casting were numerically analyzed. The filling behavior, solidification sequence, and thermal stress distribution were reproduced and the possible defects, such as cold shut and shrinkage, were predicted, Based on the simulation result, the double gating system was replaced by a single gating system, Meanwhile, the chill were used to regulate the solidification sequence of casting. To eliminate the cracks in the casting, the sand core was converted into a canulate one. By modifying the original process, the defects were eliminated and the casting with good quality was obtained.

7) Malcolm Blair, Raymond Monroe, Christoph Beckermann, Rishard Hardin, Kent Carlson and Charles Monroe Casting designs are generally based on strength of materials calculations and the experience of the designer. This process leads to incremental development of designs utilizing factors of safety, which lead to increased component weights and inefficient use of materials. In castings, unquantifiable factors (such as shrinkage, porosity, hot tears and inclusions) lead to conservative design rules. Non destructive testing does not give the designer a way to assess the effect of indications on part performance, this article describes recent work to predict the occurrence and nature of defects in casting and determine their effect on performance.

8) A. Alagarsamy, Foundries are still using trial and error methods to solve casting problems. There are benefits to using a more disciplined approach to define, identify and determine the root cause of a defect. Use of international standard defect codes for classifying the defects is illustrated. Powerful techniques such as defect mapping, questioning to narrow down the root causes and design of experiments to identify and control the variables are explored. An actual case history in solving shrinkage porosity is described to illustrate these techniques in practical use.

9) Dr. B. Ravi, Computer simulation enables visualization of metal flow and solidification in a mould, so that potential casting defects can be analyzed and prevented by appropriate changes to tooling and process parameters. There are over a dozen simulation systems available in the market today, each with several combinations of various modules. Unfortunately, there are no published guidelines for their proper selection and utilization. Many questions arise in mind regarding the application, benefits, inputs, results, accuracy, speed, knowledge and skill required for casting simulation programs. This paper presents a general introduction to casting simulation, followed by guidelines for objective selection and effective utilization of simulation programs. The above information is presented in three parts, in the form of frequently asked questions and answers. These provide a good starting point for foundry engineers exploring casting simulation for the first time. It should be noted that each software program is unique, and users should get in touch with the respective vendors for more accurate and up-to-date information.

10) B. Ravi, R.C. Creese, And D. Ramesh Design revisions are expensive and time consuming. Yet, these are inevitable because product designers have limited knowledge about casting processes and have no means to evaluate the influence of design features on castability (costs, quality and productivity). Problems appear much later, at the tooling or manufacturing stage, when it is much more expensive to incorporate changes than at the design stage. Progressive engineering companies therefore rely on design review committees, which include tooling and casting engineers, to suggest early modifications to a product design for ease of manufacture. This paper presents an intelligent design environment to assist product engineers in assessing a part design for castability. The software simulates the way casting engineers decide the casting process, parting line, cores, mold box, feeders, gating system and mold layout, and analyzes each decision to suggest how the design could be modified to improve quality as well as reduce tooling and manufacturing costs. The software also facilitates electronic exchange of information between product, tooling and casting engineers, thus improving the level of communication between them and helping compress the total lead time to complete a project

11) C. M. Choudhari, B. E. Narkhede, S. K. Mahajan In this study, it was observed that solidification simulation enables visualization of the progress of freezing inside a casting and identification of the last freezing regions or hot spots. This facilitated the optimized placement and design of feeders with improvement in yield by 15 % while ensuring casting soundness without expensive and time-consuming trial runs. In this case, the thick portion of the component was subjected to shrinkage porosity. It was the root cause for the poor strength which was leading to premature failure of the component. Proper design of gating system has immensely helped in achieving the directional solidification leading towards the feeder; thereby solving the problems of premature failure due to junction solidification and incomplete fill due to sudden variations in thickness.
Feeder was placed at last solidifying region using Auto CAST-X software. This approach has helped in minimizing the solidification related defects, thereby providing a defect free casting. This study shows that simulation can be of great use in optimizing the feeder dimensions and increasing the feeding efficiency of the casting. Both macro porosity and micro-porosity were identified as 4.47 cm^3 with 100% quality. Quality, feeding yield and feeding efficiency obtained from software were 99.89, 84.66 and 22.82 % respectively

12) Ganesh G. Patil and K. H. Inamdar Casting process is the most widely used process in manufacturing industries especially in automobile products. Systematic analysis and identification of sources of product defects are essential for successful manufacturing. Since the quality of casting parts are mostly influenced by process conditions, how to determine the optimum process condition becomes the key to improving part quality. The industry generally tries to eliminate the defects by trial and error method, which is an expensive and error-prone process. This paper presents review on a use of Artificial neural network (ANN) for the casting processes better than the other techniques such as design of experiment (DOE), inspection method, casting simulation, cause-effect diagram, genetic algorithm, fuzzy logic. ANN has challenges in the eve of prediction, optimization, control, monitor, identification, classification, modeling and so on particularly in the field of manufacturing. We discuss number of key issues, which must be addressed when applying neural network to practical problems, and steps followed for the development of such models are outlined. Artificial neural network also found that, the trained network has great forecast ability. Furthermore, the trained neural network is employed as an objective function to optimize the processes.

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