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A Review on Casting Defects Analysis for Optimization of Process Parameters to Minimize Casting Defects

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Abstract: *In today's age of globalization, foundry plays basic and versatile role in manufacturing industries. The high effective performance of foundry industry is determined by its minimum number of rejections in casting and achieving better result at minimum cost. The industries face problems like poor quality and low productivity due to constant rejection of casting components for which uncontrolled parameters or lack of skilled workers or low penetration of automation is responsible. The casting defects in industries do not occur without any disturbances in casting operations. It is due to the slight changes in execution of casting process which affects the process parameters. The defect free casting with minimum rejection and high quality at low cost is the need of time. This can be achieved by application of simulation, achieving proper gating and risering design, controlling of process parameters and standardization of casting operations. This paper is aimed to collect the reviews of researchers and explain the need to carry out casting operation in order, to improve the productivity of industry.*

Keywords: *Casting defects, casting process need, process parameters and simulation*

I. INTRODUCTION

Casting is one of the ancient and versatile processes of manufacturing or shaping techniques. The complex geometry and heavy parts of automobiles can be easily manufactured on mass production in casting. It is the process in which the molten metal is poured into the mould cavity formed by the pattern (replica of the product to be casted) and allowed to solidify. After solidification the solid object is taken out either by breaking the mould or separating the mould apart (cope and drag). The solidified piece of metal is called *casting* and the process carried out to prepare the product is called *casting process*. The place where casting takes place in a systematic manner is known as *foundry*. Any defects in design of gating system or uncontrolled parameters cause defects in casting. The defects are nothing but unwanted features which does not satisfy the customer's requirement and thus affect the quality. The defects formed may be minor or major defects. The minor defects does not affect the functioning of the component as per customer's need while major defects does. Though casting process provide great freedom to cast heavy and bulky products, it is difficult to cast intricate parts with old casting process without help of automation.

The product casted in casting may be in single piece or two parts i.e. (drag and cope) where the half mould is located in cope and other half in drag.

These are joined together at the parting line and molten metal is provided from the pouring basin to mould cavity through sprue which reduces the velocity of molten metal and strainer which acts as a filter while runners allow molten metal to run from sprue basin into mould cavity through in-gates. Runners restrict the formation of shrinkage cavity and pouring basin holds the molten metal from ladle. This gating system must not be faulty in order to achieve defect free casting. Hence it is necessary to check the composition of molten metal used for casting and proper gating system can be achieved by simulation. The mould composition is needed to be checked properly.

The changing of one process parameters may affect the functioning of other. The highest and the lowest limit of each parameter affecting the casting needed to be marked so that all factors will be achieved properly and correctly. In order to achieve this it is necessary to use well conditioned testing instruments and maintaining environmental condition. The main objective of any foundry is to increase profit margin, improve financial condition through rate of reduction of rejection in casting and achieve customer satisfaction.

The casting is divided into two parts; Expendable and Non-expendable casting. The expendable casting includes mould of sand, plastic, shell and plaster which are prepared temporary and after breaking they are non-usable again while non-expendable casting involves mould which can be used again in casting.

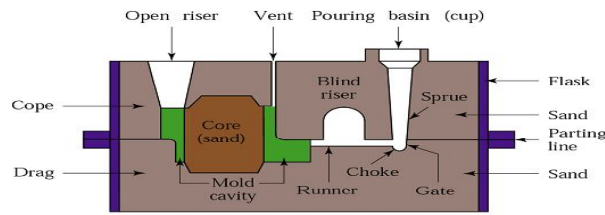
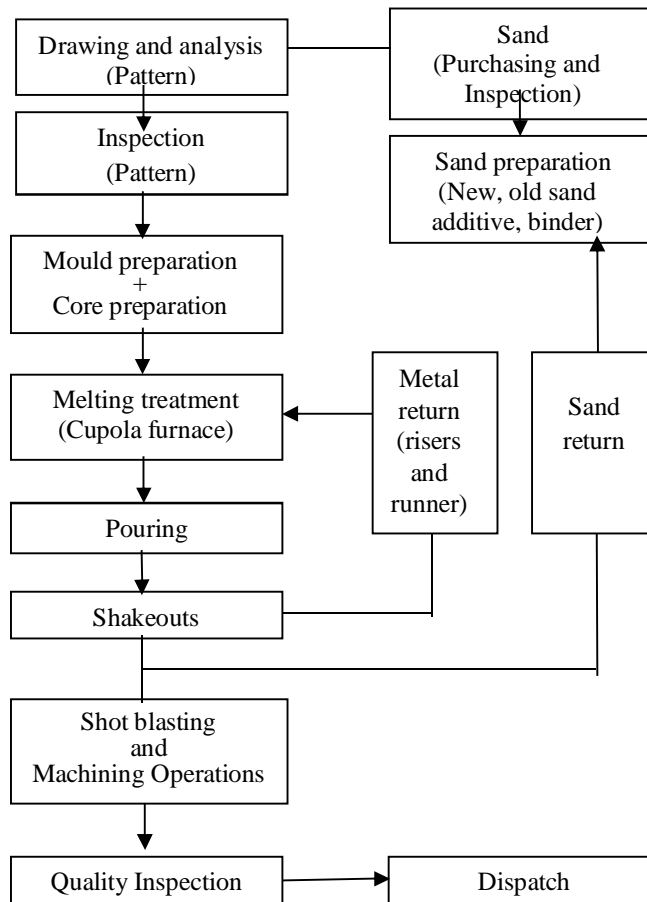


Fig.1 Metal Casting Process

To check defects in casting two, types of testing are done: Destructive and Non Destructive (NDT) which helps in determination of presence of defects. The NDT does not involve any damage to the component under testing. The varieties of defects which are found in casting may occur due to following reasons:

- 1) Faulty gating system.
- 2) Non-uniform thickness of section and corners are not sharpened properly.
- 3) Non-uniform cooling which raises internal stresses which creates cracks.
- 4) Non-uniform distribution of molten metal inside the mould due to over heating or less heating of metal.
- 5) Unskilled post treatment like shakeouts, fettling.
- 6) Inadequate mixing of sand, inadequate pattern allowances.
- 7) Improper clamping of top and bottom moulding boxes.
- 8) Inaccurate pouring temperature also excessive handling time.
- 9) Low permeability of moulding sand, soft ramming, improper cleaning of mould box, chills and metal inserts

II. OVERVIEW OF SAND CASTING PROCESS (PROCESS FLOWCHART)



III. LITERATURE REVIEW

Shubham Sharma et al. analyzed the rejection data using 7 quality control tools. This analysis helps to sort out major causes which are contributing for over 80% of the problems. The main objective of this research paper is to study defects in trumpet housing casting (Grey CI FG 250) by using quality control tools. The data collection for one year of span showed that blowholes and sand drop are the major defects in casting. This analysis helped in reduction of blowholes from 4.54% to 1.92 % and sand drop from 1.74 % to 0.81%. This analysis mainly helps in determination of major causes which results in formation of defects in casting. The analysis makes it less difficult to focus on main problems by analyzing causes for defects; some of them can be avoided by applying suggestive remedies [1].

Sidhant Karnik et al. carried out the analysis at local foundry situated at Kolhapur. It was observed that the component; bearing cover (Grey CI FG 260) was facing major defects leading to high rejection. This paper mainly focuses on identifying the factors which are mainly responsible for the large frequency of rejection. The why-why analysis conducted by the author found that there is need to make some changes in gating system to get optimum results without disturbing the production plan. This study helps in identifying the factors responsible for defects. This study shows that there is need of inter-connection between every department in foundry where including foundry head, quality head, development head need to work together to avoid defects for bearing cover. After implementation of solution and applying suggested remedies it was seen that the rejection was reduced from 23% to 3% [2].

Prashant Sharma et al. have done this analysis to study the defects of an aluminium casted part as automobile industries are using aluminium alloy wheel on large scale. The diagnostic approach has been applied to identify major defects. The shrinkage defect mainly occurs in hub of solidified wheel. The Pareto analysis determined the optimum levels of temperature of molten metal that is 700°C to 720°C as hydrogen content is stable in this range. This paper mainly deals with the detailed study of defects in aluminium alloy and improving quality of casting using 7 quality control tools [3].

Aniruddha Joshi et al. has done the analysis of defects with Pareto analysis and fish bone diagram was improve productivity of the casting of automobile component and minimize the cost without disturbing the quality of the component. The foundry has adopted manual casting operations which are used for production of required sizes and shapes; hence increases chances of mistakes in casting. The data collection of three month from foundry shows that it is necessary to change manual operation system to automatic one. After inspection of causes responsible for casting, remedial actions for each defect were suggested which reduced defect up to certain extent and mould shift rejection up to 50%. This study gives the systematic approach to find the cause of defects which occurs due to manual operations, unskilled workers and ignorance. The manual rejection reduces the total rejection in the foundry more than 30%. But if suggestive remedies were applied and automatic operating system was applied then the rejection can be reduced to more than 70% [4].

Shyam Barode et al. have carried out experimentation of rejection of casting by DMAIC approach of six-sigma methodology. This study mainly focuses on design of experiment and two-way analysis of variance technique (ANOVA) which were combined to determine the correlation between process parameters in die casting. The data collection plan was adopted and cause and effect analysis clarified that the major defect which is found in two defected items; terminal cover and din based cover is blowholes. The optimization of process parameters through ANOVA resulted into decrease in percentage rejection of terminal cover from 16.93 to 10.04% and that of din based cover from 16.62% to 8.97%. This analysis shows that to increase productivity and sustainability of the results it is necessary to maintain standardization of process and any careless behaviour or new staff arrival can make same mistake again which will lead to same rejection and decrease quality of component [5].

Sachin L. Nibulkar et al have studied gating and risering system to optimize the design using Auto-CAST X1 software. The objective of this study was to minimize rejection rate by making sand mould and casting of the part so that the results from simulation and experimentation were compared. The material used for casting was grade SG-69-45-12 and silica sand was used for moulding and wooden pattern was used to form a mould cavity. The study was carried out in four stages: design of feeder and gating system, numerical simulation with the help of Auto-CAST X1 simulation software, validation with experimental results and testing machine or comparing the results with the old one. The testing of wear plate under analysis was done by ultrasonic testing and it was observed that only the 3 plates out of 10 were rejected which reduced rejection up to 30% [6].

Virendar Verma et al. have used DMAIC six sigma approach which aims to eliminate the smallest variation in quality of raw material, operator behaviour etc. The study has been carried out at Shree Balaji Casting Samalkha, Panipat. The cause and effect analysis on the component of upper gear, lower gear, key roller sporting arm, worm gear helped to determine the major defects in these component which are misrun and blowholes. After analysis of three months of collection of data, the root factors responsible for rejection were determined. The obtained result after application of DMAIC approach shows overall reduction in casting from 6.98% to 3.10% which resulted in saving cost of Rs. 2.35 Lac approximately [7].



Bhushan Kamble et al. have proposed a systematic study to investigate casting defects and corrective actions were suggested to optimize the results. Cause and effect diagram mainly shows six factors which cause major defects and minor defects, that are working conditions, raw materials, management technology, machine and workers. Various casting defects occurring in a medium scale industry were listed out with causes of their occurrence. This study helps in achieving the defect free casting if the process parameters were controlled properly. The analysis is very useful in achieving quality casting in manufacturing industry by standardization of production process [8].

Y. V. Gore et al. has done the solidification analysis by simulation using ANSYS software. The main objective of this research is to reduce formation of hot spots in aluminium and steel casting. The various factors affecting the rate of solidification after pouring of molten metal into mould cavity has been defined by simulation. The three parameters defined during the analysis and their interaction with each other in ANOVA gives the insights on which parameters needs to be controlled as per their contribution percentage in order to minimize hot spots. It was found at the end of analysis that sand conductivity mostly affects the rate of solidification of casting. This study helps in determination of critical system parameters to control heat transfer during solidification [9].

Udhaya Chandran R. M. This investigation mainly deals with optimization of process parameters to minimize the casting defects in foundry industry. The study has been carried out in Job industry in Central India. The optimum level of process parameters has been achieved with thorough analysis by Taghuchi. This analysis focuses on the casting operations in foundry and reduces the rejection up to 47.66% [10].

Vivek Gondkar et al. This paper includes collection of basic and advanced simulation technique. For large foundries and for SME, cloud based simulation was used. The simulation has been carried out on bracket chasis. The parameters affecting the casting were determined by performing simulation on old gating system. The new gating system was developed which eliminated the defect of shrinkage porosity and reduces the number of occurrence of hot spots. This study mainly focuses on reduction of the cost of rework by reducing the percentage rejection which was 0.2% in this case. This paper represents how simulation needs to be performed to determine parameters affecting the casting as it performs solidification of molten metal, helps to design the system, optimize it and minimize the cost [11].

Aondona Paul Ihom et al. have done this research to study green compressive strength of a green sand mould using statistical approach. The analysis has been done using empirically generated data at National Metallurgical Development Centre, Jos Sand Testing Laboratory. The green compressive strength data with variation in moisture and clay content has been collected. The multiple regression model analysis for this data by considering moisture and clay content as independent variables and green compressive strength as dependent variable gives us coefficient of multiple determinations which is 0.72. This shows that the 72% variation in green compressive strength is actually due to the combined effect of moisture and clay content. It was concluded that the mathematical model is more effective for the analysis and estimation of green compressive strength [12].

C. M. Chaudhari et al. has done this study to redesign and produce a defect free casting by improving the yield of feeders and quality of casting. The several simulation trials have been carried out by AutoCAST-X software to identify optimum location of feeder where the formation of hot spots was expected. The component which was selected for analysis was subjected to high amount of shrinkage and low yield of 45%. The component taken for analysis is square shaped plate at top. This study showed that simulation can be effective for identification of location for occurrence of casting defect as it does not involve any wastage of material or labour. The simulation results were compared with experimental results and it was found that the analysis optimized the design of feeder by improvement in yield by 20% [13].

K M Maneesh et al. have described a way to minimize the health hazards in industry to make the work condition more effective and to improve poor quality and productivity of industry by minimizing casting defects. The analysis was done at public sector foundry industry. Job safety analysis was done by interviewing, questionnaire the workers and collecting data and suggesting the necessity solutions which are required to eliminate hazards and to provide safety equipment to control health issues where it was found that molten metal burns occurs majorly due to manual operations. The Pareto analysis shows that the manual operations mostly lead to mistakes and careless activities. This mainly concluded that by having experienced workers and optimising the process the minimum rejection in casting can be achieved [14].

D. N. Shivappa et al. has done this analysis at Dakshin foundry Ltd, Bangalore India. Trunion support bracket is selected for defect analysis as it has maximum production and hence having to face maximum rejection. Silica sand with Urea Furan resin binder has been used for making mould for CO₂ casting. The analysis for casting defects has been carried out through product trials in the company and remedial measures were provided which reduced sand drop defect by 75.6%, blow holes defect by 67% while mismatch defect by 83.7%. By adopting the proper corrective action and to improve the substantial quality, the standard operations



of company in casting process were improved by incorporating suggestive measures which reduces rejection in casting due to oversize by 77%. This paper plays a really important role to aware young industrialist to achieve casting with fewer defects at low cast [15].

Channarong Saikaew et al. proposed this research which is mainly concerned with optimization of clay and water content in the recycled moulding sand by using mixture of experimental design, response surface methodology, and propagation of error in casting to improve the quality of the casting. The iron casting was measured qualitatively by stereo microscope. It was found that at 93.3% mass of one time recycled moulding sand, 5% mass of bentonite and 1.7% mass of water, the parameters like green compressive sand, permeability and desirability are suitable. This paper concludes that moulding sand at proper mixture can maximize the desirability function [16].

IV. CHALLENGES IN MINIMIZATION OF DEFECTS

The main challenge faced in casting is to identify defects which are actually responsible for rejection of casting as some defects are acceptable by customers and some are not.

This requires the detail knowledge of moulding sand composition and metallurgy and proper and detailed observation of casting process taking place in industry.

The concept of minimum casting defects mainly deals with proper execution of casting process without any change in the process. But most of the industries are still based on manual operations instead of automation which leaves a space for human error. The skilled staffs which are also experienced in their respective field play a significant role in this execution process of manufacturing. The foundry industry with different departments needs to work together so that the proper co-ordination can be achieved without any miss-communication and whole focus will be directed on the main problem of casting rejection. Most of the industries still follow trial and error method to achieve desired results. But the knowledge of different method which can give the optimum results in achieving optimum levels of process parameters can lead to the minimization of time also reduction of wastage of material.

V. OBJECTIVE OF THE RESEARCH

There are various factors in production process which affects the quality and the productivity of casting majorly. It is necessary to analyze such factors to improve productivity of foundry. The foundry is dealing with problems like large casting rejection. This analysis includes study of production process at foundry in detail and provides the necessary guidelines so that the problem can be minimized.

VI. NEED FOR ANALYSIS

The global buyers demand the defect free casting and strict delivery schedule which foundries are finding difficult to meet. The foundry industries face many problems when there is rejection in casting component on large scale. The rejection of component due to casting defects not only results in wastage of materials but also creates delay in delivery of items.

The delay in delivery of items leads to disturbed schedule of production which makes the customer lose their confidence in suppliers. Hence it is necessary to adopt proper plan to meet the delivery of schedule so that the demanded items can be supplied. In order to achieve the good quality of these demanded items at minimum cost the various techniques must be adopted to minimize the casting defects.

VII. CONCLUSION

This paper mainly concerns with importance of low casting rejection in foundry where different casting defects generally found and the need to apply the suitable remedies. This will not only improve the productivity by decreasing the number of faulty casting but also reduces cost of rework needed to be done.

This enhances the effective performance of industry. The different methods for identifying the problems in casting are listed in the review like six-sigma DMAIC analysis, optimisation of process parameters by DOE, Taghuchi analysis, 7 QC tools, simulation software techniques which are mainly based on improving the quality and reducing the cost.

To achieve casting with minimum defects the main focus should be in controlling of process parameters in basic operations of casting. Simulation makes visualisation of filling process easy to evaluate and which makes it easier to determine the process parameters affecting the casting. Combination of both simulation and controlling of process parameters can achieve a defect free casting.



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