INVESTIGATION AND ANALYSIS OF METAL CASTING DEFECTS AND DEFECT REDUCTION BY USING QUALITY CONTROL TOOLS

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Abstract- Casting has various processes like Pre casting Processes, pattern making, core making, molding and mold assembly making, Casting Processes, furnace charging, melting, holding and pouring, and Post casting Processes, shakeout, inspection and dispatch etc. In India there are many foundry have followed conventional and manual operations. Today's competitive environment has, lower manufacturing cost, more productivity in less time, high quality product, defect free operation are required to follow to every foundryman. Mold shifting, Crushing, Lower Surface finish, Shrinkage, Porosity, Cold shut and Extra material are common casting defects due to these manual operations. These defects directly affect on productivity, profitability and quality level of organization. In this paper all data presented is taken from one foundry. This paper presents all data of manual metal casting operations and defects leads to rejection for this organization. The paper also represents analysis of these defects with Pareto and Cause and Effect diagrams to know correct cause and correct remedial factors to improve quality level and productivity of organization.

Index Terms- Manual Metal Casting Activities, Casting Defects, Pareto Analysis and Cause and effect Diagram

I. INTRODUCTION

Metal casting is one of the direct methods of manufacturing the desired geometry of the component. Casting or the process of foundry is very efficient and effective manufacturing process, which can transforms raw material into discrete output. The principle of manufacturing of casting involves creating a cavity inside a sand mould and then pouring molten metal directly into mould cavity. Casting is very versatile process being used for number of engineering applications in today's world. An automotive component is common and popular application of metal casting. There are several methods involved for production of metal casting like manual and automatic.

In India manual casting production method is most common in number of foundries. The activities involved in casting process are, Pattern making for creation of mold box, Core making for insertion in mold assembly, fitting of pattern, gating system and sand for mold preparation, remove prepared mold and placed for pouring, fill the mold cavity with molten metal, allow it to solidify and at last, remove the cooled desired casting. These activities are commonly used because of its simplicity in process, economic to operate and easy to produce small size castings. In this work manual metal casting operations of an automotive component producing foundry are studied where components of different size and shape are produced. In this study defects of casting processes are known which directly affecting rejection level of organization and reduces productivity and quality level of industry.

The defects need to diagnose correctly hence Pareto chart and Cause and Effect Diagram have been used to identify and classify the reasons that are responsible for defective casting production and lower productivity of organization.

II. LITERATURE REVIEW

Wilson et al. (1993) have defined the Root Cause Analysis as an analytical tool that can be used to perform a corrective and comprehensive, system based review of critical defects. It includes the identification of the root and contributory factors, determination of defect reduction strategies, and development of action plans along with measurement strategies to evaluate the effectiveness of the plans.

Canadian Root Cause Analysis Framework (2005) says that root-cause analysis is an important component of understanding of defects. The team begins by reviewing an initial understanding of the event and identifying unanswered questions and information gaps. The information-gathering process includes interviews with staff, who were directly and indirectly involved, examination of the physical environment where the event and other relevant processes took place, and observation of usual work processes. This information is analyzed into a final understanding, which is then used by the team to begin portion of the analysis. Similarly, to solve a problem, one must first recognize and understand what is causing the problem. This is the essence of root cause analysis. According to Perzyk (2007) case study in foundry industry by, Pareto chart shows that the foundry staff should concentrate on reducing defects like ’sand inclusions’ and ‘gas holes’, which make up 72% of all defects. Pareto diagrams can therefore be particularly useful in defining the targets. Pareto charts show the most frequently occurring factors and help to make the best use of limited resources by pointing at the most important problems to analyze.

Chandna and Chandra (2009) studied forging operation that produce six cylinder crankshafts used in trucks and buses. With the help of Pareto diagrams critical areas are identified and forging defects of crankshaft have been prioritized by arranging them in decreasing order of importance. Then Cause and Effect Diagram (CED) is applied to explore possible causes of defects through brain storming session and to determine the causes, which have the greatest effect. The corrective measures reduce the rejection rate from 2.43% to 0.21%.

Khekalei et.al (2010) presented another case of wastage reduction in a belt manufacturing industry located in the Virabha, India which produces world class automotive belts and hoses. The main raw material for producing this automotive belt is rubber. Others raw materials are biased fabric and cord. From many years consumption of raw material was not taken seriously as rubber is reusable. But other raw material that is biased fabric and cord consumption was increased drastically which resulted in increased in the production cost of belt and reduced profit margin. Wastages in the belt manufacturing process are- cord wastages, fabric wastages, and in-process wastages. Cord and fabric wastages occurred during drum building process while in-process wastages occurred during cutting operation. DMAIC (Define, Measure, Analyze, Improve and Control) has been used to reduce cord wastages in belt manufacturing. The analyze phase focuses on the potential causes that are identified by using cause-and-effect diagram, which have the maximum impact on the operational wastages. CED presents a chain of causes and effects, sorts out causes, organizes relationship between Critical-To-Quality (CTQ) and root causes. After analyzing collected data, it is found out that tension setting in drum building and left over cord were the major causes for high cord wastage. The result showed reduction in cord wastage from 549531 to 17240, also the Sigma Level is improved from 1.37 to 3.6.

Mohiuddin Ahmed, Nafis Ahmad (2011) works for minimization of defects in lamp production process by application of Pareto analysis and Cause and Effect Diagram. They worked for zero waste and zero defect aim. They studied all lamp production process with its production data. They also work for data collection of all steps involved for lamp production with month wise rejection in group production system. The author applies Pareto analysis to all defects and finds major and minor contributors. So finally author applies cause and effect diagrams to each defect and find out main factor. So they suggest cause and effect diagram is very use full in indicating the appearance of abnormalities of process in the form of excessive variations of process parameters. Uday A. Dabade and Rahul C. Bhedasgaonkar (2013) have put their emphasis on casting defect analysis using Design of Experiments and Computer Aided Casting Simulation Techniques. They work to analyze the sand related and methoding related defects in green sand casting. They applied Taguchi based orthogonal array for experimental purpose and analysis was carried out using Minitab Software for analysis of variance and analysis of mean plot. Also they worked for shrinkage porosity analysis using casting simulation technique by introduction of new gating system design. So the results obtained to them with new gating and feeding system design are reduction in shrinkage porosity about 15% and improvement in yield about 5%. From the literature review it is revealed that successful application of Pareto analysis and CED can significantly reduce the defects of manual casting operations and increases efficiency. In this paper sand preparation, mold making, pouring and shakeout processes are considered for reducing defects rate.

III. METHODOLOGY OF THE STUDY

There are varieties of problems related to product quality and productivity in industries due to varying degrees of abnormality and inefficiency, which ultimately causes rejection of components. The study conducted in automotive component manufacturing foundry where mold shifting, crushing, shrinkage, porosity, flashes, surface finish, buckling and cold shut-Mis-run are the most important defects observed. The percentage occurrence of these defects is mold shifting 5.30%, crush 2.11%, shrinkage 4.34, cold shut/Mis run 3.14%, surface finish 4.56%, buckling 4.66%, porosity 3.32%, fins/ flashes 6.89%. The defects are due to improper mold making process, improper sand preparation process and improper pouring process. In this paper, the identification of defects corresponding to manual operations has been taken. With the help of Pareto diagrams, the defects in every step are arranged in decreasing order of occurrence. The cause and effect diagram is used to organize and graphically show interrelation ship between various causes of problems.

IV. OVERVIEW OF PRODUCTION LINE

An automotive components like Engine flange, Engine flange, Cylinder head cover, Bearing Housing, Flange for Inlet, Housing for Crank Shaft, Trance Case Cover, Pipe for Turbocharger, Inlet Hose, Pillow Block, Base Plate And Housing Lever etc. are produced in foundry which is studied.

All these components are manufactured in this foundry with manual operations of sand preparation, mold making, melting, pouring and shakeout. So, all the process details are explained below with process flow chart. The process flow chart clears all operational details with sequence of operations occurred in foundry industry. But manual activities are explained in detail below.

Although, the metal casting producing plants are jobbing or production type, the basic operations are never going to change for any component of metal casting.

The foundry studied has jobbing type of metal casting operations. So to operate this plant skilled labours are required. Hence this is totally labour dependant organization. The foundry industry has variety of operations which are performed for production of required sized and shaped metal casting with following process sequence shown in figure.1.

Activities performed manually are:

1. Sand Preparation:

In foundry industry sand is used for mold making process. In this industry there are three mullers which are used for mulling and mixing of sand with other constituents like water, bentonite etc. all the process related to mulling like insertion of sand etc. is done manually. So due to this manual operation sand properties are not properly obtained and production of prepared sand is in less quantity. So it reflects on overall productivity of mold boxes.

2. Mold Making:

Mold is nothing but small cavity which when poured with molten metal produces a casting of desired shape. The process of this making mold with mold assembly preparation is known as mold making. Mold making is a major important process of sand casting. In foundry industry this mold making process is performed manually with hand controlled tools. The activities like placing of pattern, mold box, insertion of sand, insertion of gating system components, ramming of sand in mold box and mold assembly formation are some processes which are followed manually. In organization cope and drag molds are used.

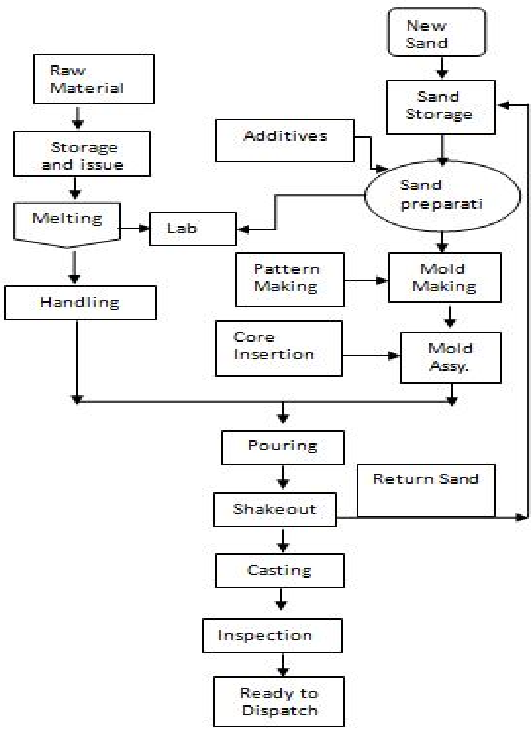

Figure 1 Process Flow Chart

3. Pouring:

Pouring is the process of foundry which is nothing but insertion of molten metal in molds for production of casting. Pouring section includes ladles which are used to pour the molten metal in molds. Prepared molten metal is poured in ladles which are taken away to pour into molds manually. In industry four hand ladles are there which are used to pour molten metal in mold box.

4. Shakeout:

After molten metal has been poured into mold boxes it is permitted to cool and solidify. When the casting has solidified it is removed from molding box. This operation is marked as Shakeout. In organization shakeout is also done manually. The process like dump the mold assembly upside down on ground. Break the sand around the casting by striking against the sand with the back of hammer, the casting can then be pulled out of the sand with the hook bar etc .so all is done manually.

V. DATA COLLECTION

The rejection data was obtained from foundry and placed in tabulated form for convenience to use and understand. Rejection check sheets are generally large data sheets showing the total information about rejected items. Simplified data from rejection sheet is represented in the following table. Data shows the total pouring per month and data is of three months. Rejection of total components is given in following table. 1.

Table. I. Defects and Percentage of Occurance

Defects	Job rejection Percentage
Mold shifting	5.30
Crush	2.11
Shrinkage	4.34
Cold shut/Mis-Run	3.14
Surface Finish	4.56
Buckling	4.66
Porosity	3.32
Fins/ Flashes	6.89

VI. PARETO CHART

Pareto Analysis is conducted for identification of major defects those are contributing in major rejection percentage. Pareto gives correct identification hence it is conducted. Pareto shows all defects and their related percentage. So according to Pareto fins and flashes are major defects and other contributing to it. It was necessary to find out actual reasons behind the defects with use of Cause and Effect Diagram for analysis purpose. All cause and effect diagrams of each defect are shown below.

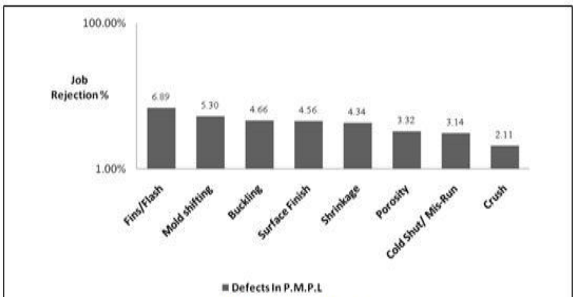

Fig. 2 Defective Percentage

VII. CAUSE AND EFFECT DIAGRAMS

Cause and Effect Diagram is one of the approaches to enumerate the possible causes. Following section shows all cause effect diagram for all defects occurred in organization All below figures shows the cause and effect diagrams for each defect. This determines the potential cause which causes defects. These defects after the particular cause has been identified, remedies are suggested to eliminate these defects.

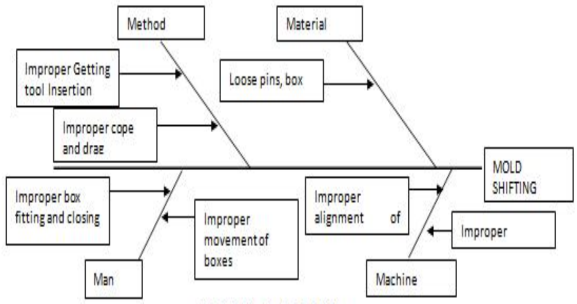

Fig.2. C.E.D. for Mold Shifting

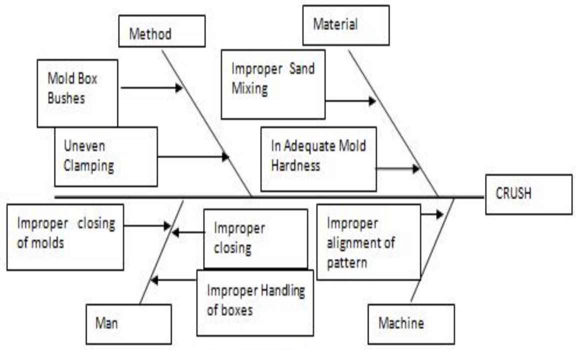

Fig.3. C.E.D. for Crush

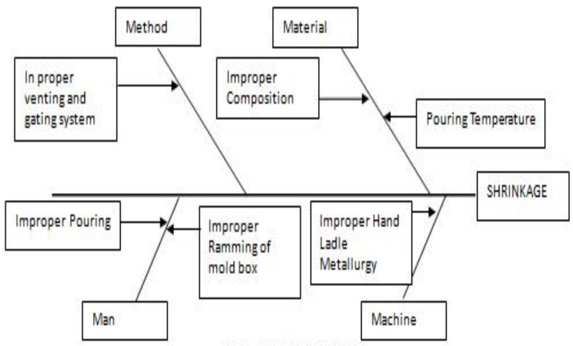

Fig.4. C.E.D. for Shrinkage

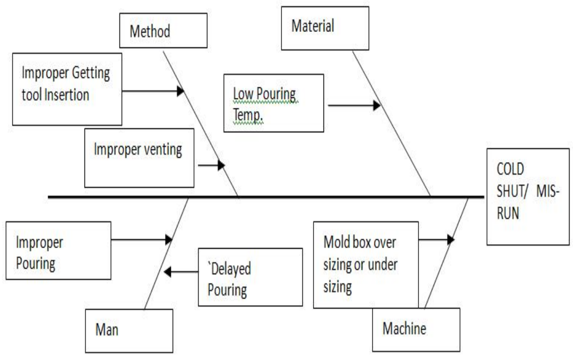

Fig.5. C.E.D. for Cold Shut/ Mis-Run

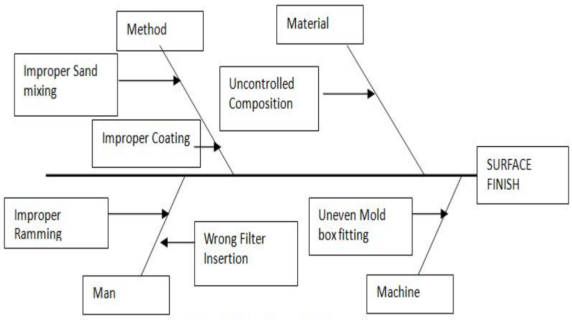

Fig.6. C.E.D. for Surface Finish

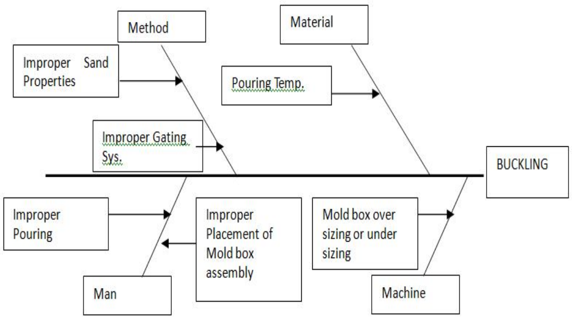

Fig.7. C.E.D. for Buckling

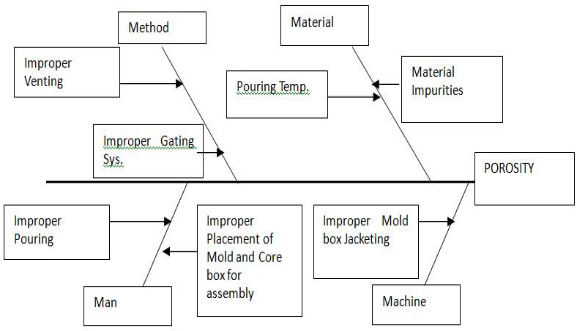

Fig.8. C.E.D. for Porosity

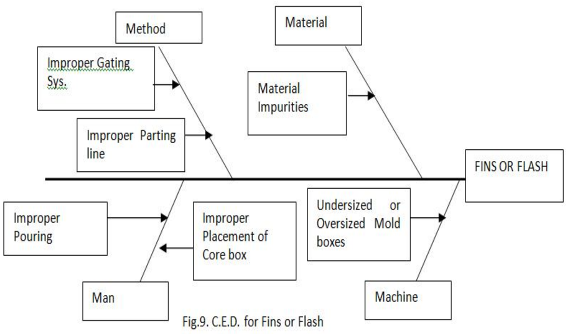

Fig.9. C.E.D. for Fins or Flash

VIII. REMEDIES TO CAUSES AND EFFECTS

So all these defect are due to manual operations of metal casting. These defects lead to loss of productivity and profit to organization. Following some remedial issues are suggested for minimization of these losses.

1. Change operating system from manual to automatic
2. Change hardness of mold box; install Air blasting rammers or automatic rammers for ramming of sand in mold box.
3. Proper clamping of mold box on mold machine or use automatic mold box production machine.
4. Use appropriate sand adequate green compressive strength and other mixing properties; it is possible with automatic mulling machines.
5. For smooth and in time pouring replace manual hand ladles with automatic monorail system. Also maintain pouring temperature 1418 to 1432ºc than existing 1450 to 1470°c.
6. Change manual shakeout to vibrating shakeout system

So by identifying and analyzing cause and effect diagram above remedies are suggested for operations. But the analysis is largely depends on experience and practice.

IX. RESULTS AND DISCUSSION

1. As some defects like shrinkage, porosity and cold shut/ Mis run are depends on pouring system and temperature, So by keeping pouring temperature 1418 to 1432ºc help to reduce all defects. Automation of pouring system will be very effective.
2. The molding will require replacing by automation but for keeping mold hardness within range, if air blasting rammers are used then it minimizes the defects like crushing, Fins/ flash production and mold shifting up to 50%.
3. The defects like buckling, surface finish and porosity also are minimized with changing the sand properties. So sand mulling is required to do carefully with addition of correct percentage of additive.

So by CED methodology it is easy to understand the causes of defect production. So some easily possible main remedies are followed hence it minimizes the defects up to more percentage.

CONCLUSION

Pareto principle and cause effect diagram are used to identify and evaluate different defects and causes for these defects responsible for rejection of components at different stages of manual metal casting operations. The correct identification of the casting defect at initial stage is very useful for taking remedial actions. This paper presents the systemic approaches to find cause of defects occurred due to manual operations. So finally it was found that the manual metal casting operations are done with some negligence and carelessness. So by suggesting some other remedial issues and by implementing possible of them reduces total rejection more than 30%.If suggested remedy of automation will be implemented it reduces all defects more than 70%. This systematic study proves that by means of effective analysis of tools and processes, it is possible to control the casting defects.

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