INVESTIGATION AND ANALYSIS OF METAL CASTING DEFECT BY USING QUALITY CONTROL TOOLS ON TRUMPET HOUSING OF A TRACTOR: A CASE STUDY

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Abstract: Casting is very versatile process used in a number of engineering applications. One of the application is in the production of Trumpet Housing used in a tractor for supporting its rear axle shafts. But due to poor quality of the foundry industryit has become difficult to meet defect free and strict delivery schedule in the production process. Hence to eradicate this situation, Quality Control Tools are being introduced for getting the best results from the production process. Total Quality Management is used in this paper for reducing the various casting defects and get the desired result. Casting defects generally occurs due to improper sand properties, improper gating system and labour skills. Due to such high rejection rates the confidence of the customer on the product is lost. Hence Quality Control Tools like Pareto Chart, Cause and Effect Diagram are used to identify and classify the reasons for defects in the production system and reduce them by using various remedial measures.

Keywords: -Casting Defects, Cause and Effect Diagram, Gating system, Pareto Chart, Quality Control Tools, Total Quality Management,Trumpet housing

1. INTRODUCTION

The trumpet housing used in tractors is used for supporting the right and left hand axle shafts. A normal duty trumpet housing is used for analysis of its defects. The housing is made of grey cast iron(FG250) [12]. With a total production of 8017 trumpet housings in a year, 953 were found defective due to different casting defects [10]. By learning Quality Control Tools [1] from Fábio A. Fernandes"On the use of quality tools: a case study"and Total Quality Management [3] from "Scrap reduction by using total quality management tools" the type of defects are being studied and ranked according to their severity i.e. the defect that caused maximum impact on the production process is treated before other defects. This gives a total idea of the major defects that are reducing the efficiency of the production system. The casting process used in production is known as Sand Casting [8]. It accounts for 80% of the cast product and is used for both ferrous and non-ferrous metals. Silica sand is used for the production of molds and can be found near beaches or extracted by crushing sandstone. All materials used for manufacturing of sand mold and cores are termed as molding materials. The right choice of the composition of a molding mixture is of prime importance.

Molds that are made from sand are very economical. A suitable bonding agent(usually clay) is mixed with the sand. This mixture is then moistened with water to gain the strength and plasticity of the clay, to make the mixture suitable for molding purposes.

2. LITERATURE REVIEW

In this research paper we have focused on increasing the efficiency of the manufacturing process by studying the process and then using some tools for effectively reducing these defects. Casting is one of the direct methods of manufacturing the desired geometry of any component. The foundry industry suffers from poor quality and productivity due to large number of process parameters, combined with low manufacturing automation and shortage of skilled workers as compared to other industries [8]. The major rejected Trumpet Housing castings are analyzed by using "Defect Diagnostic Approach"[15]. At first all the defects are studied. [11] Paper on defects and remedies of casting process is used for the study of different defects and their remedies. This detailed study is later used in the manufacturing industry of trumpet housing where defects in the casting process were reaching skies and needed to be improved. For this purpose [4] paper on

Reduction of Rejected Components in an Automobile Industry is studied which gives detailed about the various processes going in the industry and the root causes of the defects. The major defects are identified by using Quality Control Tools. [2] Paper on Implementation of Quality Control Tools in an Automobile Organization to reduce rejections of Casting Components is studied. This paper has detailed information of how to use the SQC(Statistical Quality Control) tools are applied and also the use of software Minitab 17 for making the process more accurate and efficient [6].Next Root Cause Analysis is applied in the process by using Brainstorming sessions and accumulating every data to a defined conclusion to solve the problem.

Identifying the defect correctly is the most important step in the casting defect analysis. Then the identification of the sources of the defect is to be made. By taking the necessary corrective remedial actions defects can be controlled. If wrong remedial actions are implied it can make the problem complicated and severe.

3. CASTING DEFECTS

Various casting defects such as Shrinkage defect, Blowholes, Cold Shut, Misrun, Gas Porosity, Mismatch, Cracks, Sand Burning, Fin, Sand Drop makes the production of molds inefficient and leads to higher rejection rates in the products. Hence to reduce these defects various remedies are used. Hence to identify the remedial measures for analyzed defects various Quality Control Tools are used.

4. PRODUCTION PROCESS

The Trumpet Housing is produced by the following production processes:-

- Raw Material Procurement
- Melting
- Metal Inspection
- Knock out
- Shot Blasting
- Fettling
- Inspection
- Casting Inspection Report
- Re-Shot Blasting
- Painting

4.1Properties of sand used in this foundry

The grain size of foundry sand is very uniform with approximately 85-95% of the material between 0.6mm and 0.15mm sieve sizes. The particle is sub-angular to round. This foundry sand is non-plastic and has low absorption properties. The specific gravity of foundry sand varies between 3.39 to 4.55 and foundry sand has a moisture content of 6.0-8.1%. This foundry sand consists of silica sand coated with a thin film of residual binder, dust and burnt carbon. Silica sand is hydrophilic, hence attracts water to its surface.

4.2Analysis of rejections of all defects over a year

For analyzing the rejected Trumpet Housing castings Defect Diagnostic Approach (DDA) is used. The data of total rejections in the Trumpet Housing castings of one year is collected from the industry as shown in table below:

TABLE 1- Rejections of Trumpet Housing due to different defects

DEFECT	REJECTED QUANTITY	CUMULATIVE %
Blowhole	364	38.19
Sand drop	140	52.88
Core gas blow	137	67.26
Depression	109	78.69
Scab	37	82.58
Box lift	28	85.51
Core lift	27	88.36
Shot pour	23	90.76
Mismatch	14	92.23
Broken casting	13	93.59
Leakage	12	94.85
Mold burst	9	95.80
Core shift	9	96.74
Micro porosity	7	97.47
Mold broken	6	98.12
Sand inclusion	5	98.63
Slag	4	99.05
Cold metal	3	99.37
Crack	3	99.68
Chilling	2	99.89
Over grinding	1	100

When the total rejected quantity of a particular defect is divided by the total number of defects, it gives us the cumulative % of that particular defect.
For e.g. - the rejected quantity due to the defect blowhole = 364

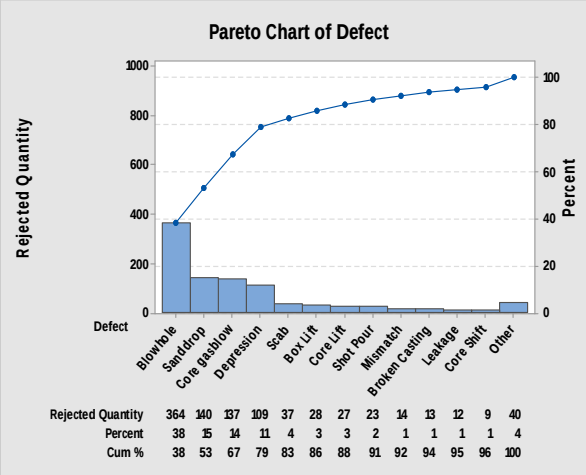
Total number of defective pieces = 953

So, Cumulative percentage = 364/953 = 38.19%

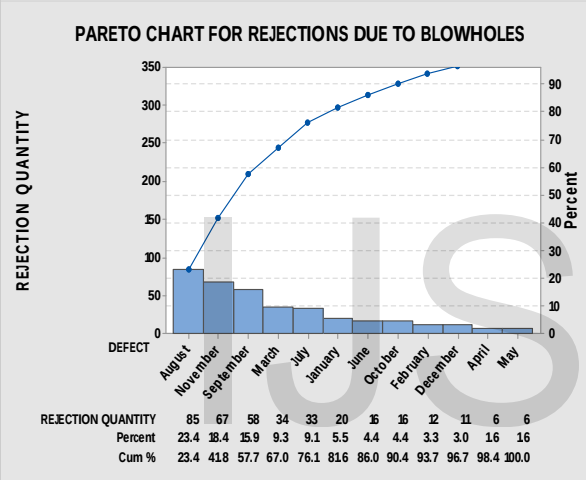
Total rejection percentage = 953/8017 = 11.887%

These values are fed into Minitab 17 Software through which the cumulative percentage is obtained. It can also be calculated by dividing rejected quantity due to particular defect with the total number of defects. Encrypting these values on the Minitab 17 sheet, then selecting the Pareto option gives a diagram showing the frequency of occurrence of all the defects. The one with the highest frequency is placed first and with least frequency at the last.

Using the Pareto Chart we conclude that the major rejections in the castings of Trumpet Housing are due to Blowholes, Sand Drop, Core Gas Blow, and Depression. But for getting the reasons behind these defects another Quality Control Tool is used known as Root-Cause Analysis or Ishikawa Diagram. The major defects in the mold casting occur due to the evolution of gases. They are also known as Gas Holes. Blow holes are spherical, smooth walled cavities. It is of two types, Pin hole and Sub-surface hole. The evolved gases are trapped on the surface of the casting that results in a cavity. By providing venting channels, reducing the amount of gases, reducing moisture content of sand, improving the gas permeability, by reducing bentonite content, the blowholes can be reduced drastically.



(a)



(b)

Fig. 1 Pareto charts for the defects (a) Pareto Chart for overall rejections due to various defects (b) Pareto Chart for defects due to Blowholes

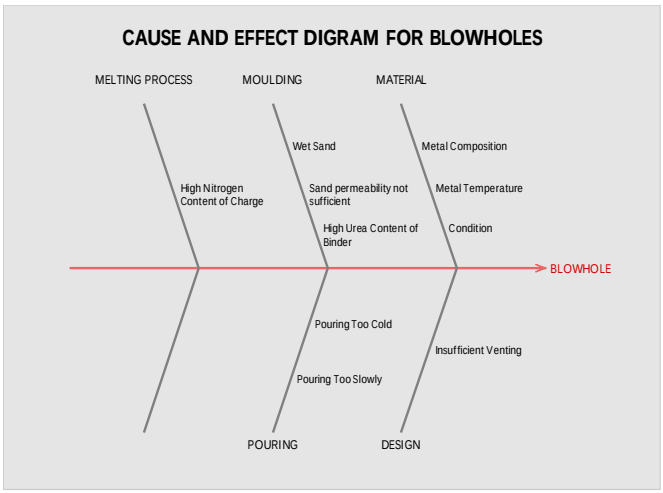


Fig. 2-Cause and Effect Diagram for Blowhole Defect

This diagram is also known as Ishikawa Diagram. It is used to collect different opinions of people working in different departments (Quality Manager, Supervisor, Workers) collecting their data after brainstorming various causes of the defects and representing it in a diagram. To analyze which problem is more severe, a Cause Effect Analysis for Blowholes is made.

5.FACTORS RESPONSIBLE FOR BLOWHOLES IN TRUMPET HOUSING CASTING:-

- Wet sand
- Sand permeability not sufficient
- Too much binder
- Insufficient venting

5.1Solution implemented for wet sand

The sand that is being used contains a higher value of moisture content ranging between 6%-10%. Due to this the amount of vapor formed due to evaporation is more leading to more blowhole defect. For reducing this high moisture content, molding sand is dried at temperatures of 105 – 110 degree Celsius. Due to this the moisture content reduces to a level of 4.3 – 4.6%. This type of sand has optimum working range with an affective green compressible strength and permeability. Although the moisture content must not be too low. It will decrease the strength of the mold.

5.2Solution implied towards escape of gases

The internal cavities should be designed such that the gases evolving from the cores of molten metal could easily escape. Sand burned into core holes and fins are difficult to remove because of small and long size of internal cores. Hence providing access holes will help to vent core gases as well as core sand to be removed out of the system. Another way of solving this problem is by changing the position of casting with reference to parting plane. By bringing the casting into the drag the core gases are properly vented.

6. ANALYSIS OF SAND DROP DEFECT

Sand drop or sand crush is an irregularly shaped projection on the cope surface of a casting. This defect is studied on a monthly basis and is diagrammatically shown on a Pareto chart followed with Cause and Effect analysis.

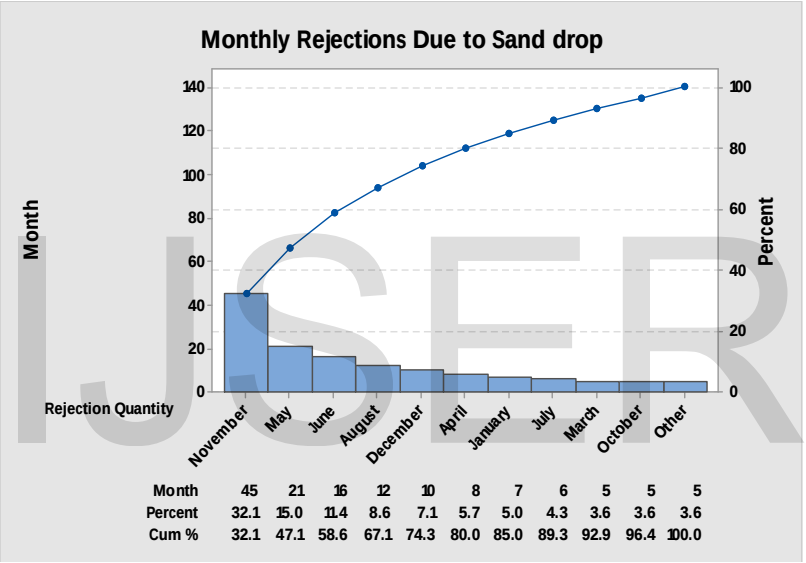


Fig. 3- Pareto Diagram for Monthly Rejections due to Sand Drop Defect

Total rejections in a year due to sand drop = 140
Total production in a year = 8017
Hence rejection percentage = 1.75%

We also performed brainstorming session with the Lab Incharge, Quality Manager, Supervisor and discussed different reasons for the sand drop defect which were collected in a Cause and Effect Diagram.

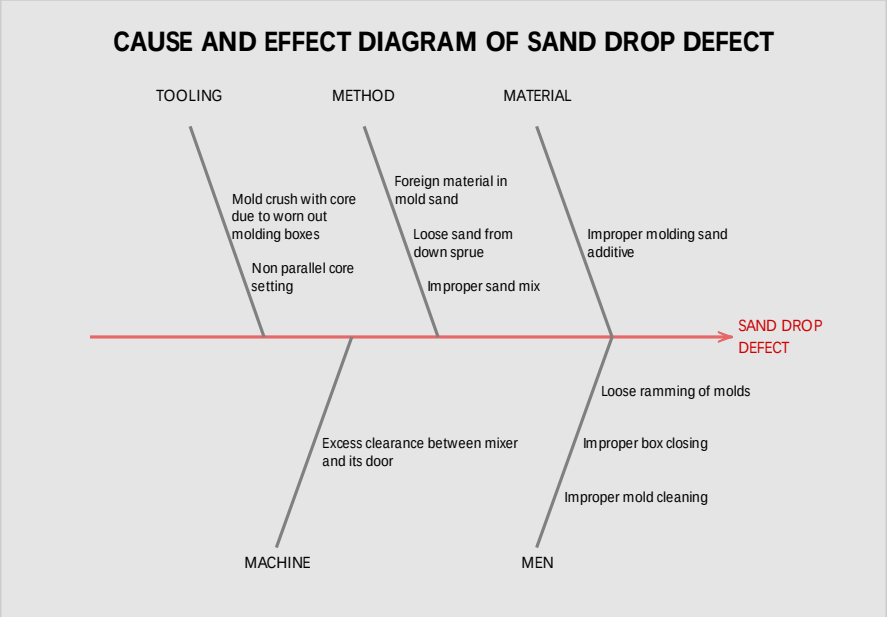


Fig. 4- Cause and Effect Diagram for Sand Drop Defect

6.1 Factors responsible for sand drop in trumpet housing casting

- Loose sand from down sprue passes with the metal
- Improper molding sand properties
- Foreign material in molding sand
- Improper mold cleaning
- Improper mixing of sand
- Excess clearance between mixer and mixer door

6.2 Solutions implemented

- **For excess mixer door clearance**
  Mixer door adjustment to reduce excess clearance
  Mixer design modification to increase the overlap

- **For improper sealed runner bar ends by operator**
  Plugging and sealing of runner bar open ends by cold box core piece
  Molding the line expansion to increase number of molding boxes to give sufficient cooling time

TABLE2 - Rejection Data After Successful Implementation of Solutions (for Blowholes Defect)

Month	Rejection	Production per month	Rejection %
January	9	480	0.11
February	5	514	0.06
March15	249	0.19	
April	3	508	0.04
May	2	578	0.02
June	7	833	0.09
July 161129	0.20		
August	31	865	0.39
September 25	835	0.31	
October	5	476	0.06
November 31	1432	0.39	
December	5	118	0.06

Total production = 8017
New number of defects = 154
% Rejection due to blowholes = 1.92

TABLE 3 - Rejection data after successful implementation of solutions (for Sand Drop Defect)

Month	Rejection	Production per month	Rejection %
January	4	480	0.049
February	3	514	0.037
March	2	249	0.024
April	6	508	0.074
May	11	578	0.137
June	6	833	0.074
July 2	11290.024		
August	7	865	0.087
September 2	835	0.024	
October	3	476	0.037
November 16	1432	0.199	
December5	118	0.062	

Total production = 8017
Total number of sand drop defects = 67
% Rejection = 0.81

7. Final cost reduction after the drop in percentage rejection:-

Total revenue loss due to blowhole before implementation of quality control tools was Rs.5,38,720 and the revised revenue cost has been reduced to Rs.2,27,920
Total revenue loss due to Sand drop defect before the implementation of quality control tools was Rs.2,07,200 and revised revenue cost has been reduced to Rs.96,200
Hence total reduction in cost = Rs.1,11,000

As shown in Table 2 and 3 the total major defects i.e. blowholes and sand drop respectively are analyzed during the whole production process. As these defects are major cause of the rejections in the castings thus eliminating them will solve more than 50% of the problems. By applying the Quality Control Tools we studied the defects which include their monthly analysis and using brainstorming sessions with the staff members at the same time. Combining both these solutions a final solution is made for eliminating the defects which after being applied to the production process lead to significant reduction in the percentage rejection thus reducing costs and making profit for the industry.

- Pareto diagram for defects have been drawn and the major rejections are due to Blowholes and Sand drop and it was noted

8.CONCLUSION

to be higher in the months of August and November and lower during April and May.

- Blowholes rejection rate has been reduced to 1.92% from 4.54% with a total savings of Rs.3,10,800
- Rejection rate due to Sand drop has been reduced to 0.81% from 1.74% with a total savings of Rs.1,11,000

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