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

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Abstract

Casting is one of the direct methods of manufacturing the desired geometry of the component. Casting defects result in increased unit cost. The defects need to be diagnosed correctly for appropriate remedial measures; otherwise new defects may be introduced. Unfortunately, this is not an easy task, since casting process involves complex interactions among various parameters and operations related to metal composition, methods design and molding etc. Check sheets help to study all the defects easily. Pareto chart and Cause and Effect Diagram are very useful to identify and classify the reasons which are responsible for defective casting production and lower productivity of organization. While Ishikawa's diagram of cause & effect or "fish bone" diagram makes possible identification of sources of problems formation, helps qualify a sequence. Rejection data is analyzed using seven quality tools. Analysis helps to sort out the major causes which are contributing for over 80% of the problems.

I. INTRODUCTION

A. Sand casting

Sand casting is a metal casting process characterized by using sand as the mold material. It accounts for about 80% of cast product and can be employed for both ferrous and non-ferrous metals. In addition to the sand, a suitable bonding agent (usually clay) is mixed or occurs with the sand. The mixture is moistened typically with water to develop the strength and plasticity of the clay and to make the aggregate suitable for molding. The sand is typically contained in a system of frames or mold boxes known as a flask. Sand used in mold making of trumpet housing casting is basically silica sand. The fusion point of pure silica is 1760 °C; however the sands used in this industry have a lower melting point due to impurities. For lower melting point metals, such as cast iron and non-ferrous metals, lower purity sand is used (between 94 and 98% pure).

B. Casting defect matrix

TABLE 1
Defect Matrix

Defects	Possible cause	Remedies
Shrinkage	Unavailability of feed metal as the metal solidifies.	Liquid metal under pressure should continuously flow.
Blowholes	Gases entrapped by solidifying metal on the surface of casting	Improve core venting, reduce amount of gas and reduce quantity of binder.
Cold Shut	Two metals streams do not fuse together due to lack of fluidity in molten metal.	By maintaining proper pouring temperature, modify gating system.
Misrun	Metal unable to fill the mould cavity completely, leaves unfilled portion.	Adjusting proper pouring temperature, modify design.
Gas Porosity	Formation of bubbles with in the casting after Metal has cooled.	Improved metal composition to improve fluidity, pour metal as rapidly as possible.
Mismatch	Shifting of molding flashes.	Use of proper molding box and closing pins.

Cracks	Thermal contraction, liquid pressure drop, vacancy super saturation.	Reduce die strength, add cold dust, reduce pouring temperature and use chills.
Sand Burning	Sand subjected to high temperature, temperature of liquid metal too high.	Use of pure silica sand, reduce pouring rate, reduce dust content and betonies.
Fin	In correct assembly of core and moulds, improper sealing.	Proper clamping of cores, proper clamping of molds.
Sand drop	Low green strength blocks.	Increasing the mold hardness.

C. The 7 quality control tools

Following are the 7 QC Tools

- 1) Process Flow Diagram: It gives brief information about the relationships between the process units.
- 2) Cause and Effect Diagram (Fishbone): By using Fish bone diagram, all contributing factors and their relationship with the defects are displayed and it identifies problem.
- 3) Control Chart Analysis: Control chart analysis helps in the following ways.
 - It helps in monitoring quality in the process.
 - To detect non-random variability of the process.
 - To identify assignable causes.
- 4) Check Sheets: Using check sheets data collection and analysis is easy. It also spots problem areas by frequency of location, type or cause of the defect.
- 5) The Pareto Diagram: Pareto diagram is a tool that arranges items in the order of the magnitude of their contribution. It identifies a few items exerting maximum influence.
- 6) Scatter Plot: For identifying a potential relationship between two variables Scatter Plot is used. By using this plot, a positive, negative or no relationship between variables can be detected.

7) Histogram: It represents a visual display of data observed frequencies versus the number of defects are given in this histogram. The height of each bar is equal to the frequency occurrence of the defects. The shape of histogram shows the nature of the distribution of the data.

D. Objectives

The general objective of this research is to investigate and study the defects in Trumpet Housing casting by using quality control tools. Reduction and minimization in defects can improve profit and performance of an organization.

E. About The Product

Trumpet housing on tractors fitted with GT 1044 and GT 1540 transmissions supports the right and left hand axle shafts. Material used for the casting is Grey cast iron FG250. Composition is given below.

TABLE 2. Composition of Grey Cast Iron

Hardness range	180-222
Total carbon %	3.15-3.30
Silicon %	1.6-1.9
Manganese %	0.6-0.8
Sulphur %	0.12 Maximum
Phosphorous %	0.3 Maximum

II. RESULT ANALYSIS AND DISCUSSION

A. Historical data analysis

To find the rejections in castings, data for occurrence of defects for one year was collected from one of leading Trumpet Housing casting industry. Using historical data analysis, check sheets have been prepared which helps to identify occurrence defects in trumpet housing castings.

TABLE 3. Rejection in Casting

Defects	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	88.35
Shot pour	23	90.76
Mismatch	14	92.23
Broken casting	13	93.59
Leakage	12	94.85
Mould burst	9	95.80
Core Shift	9	96.74
Micro porosity	7	97.48
Mould broken	6	98.11
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

Total defects occurring over a year=953
 Total production during a year=8017
 Overall rejection percentage for one year=11.89

A. Pareto analysis for work data of one year

Using Pareto chart, as below we can conclude that the major causes for the rejections in Trumpet Housing castings are due to Blowholes, Sand drop, Core gas blow and Depression.

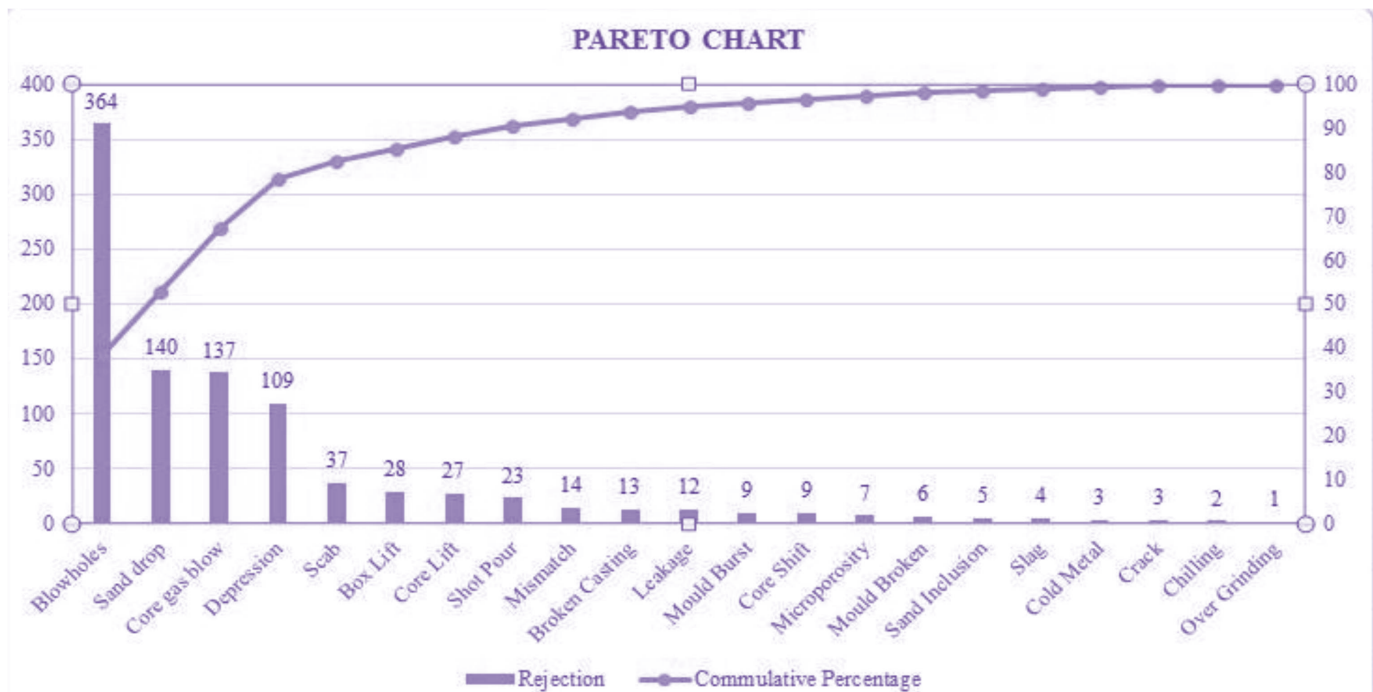


Fig. 1. Pareto Chart For Rejection Of Trumpet Housing For One Year.

It is necessary to find out the actual reasons behind these defects, to find the reasons behind these defects use of Ishikawa diagram was made which is also called as root-cause analysis.

C. Detailed analysis of major defects

1) Monthly rejection due to Blowholes:

TABLE 4. Monthly Rejections Due To Blowholes

Month	Rejection due to blowholes	Production per month	Annual rejection percentage
January	20	480	0.25
February	12	514	0.15
March	34	249	0.42
April	6	508	0.07

May	6	578	0.07
June	16	833	0.20
July	33	1129	0.41
August	85	865	1.06
September	58	835	0.72
October	16	476	0.20
November	67	1432	0.84
December	11	118	0.14
Total	364	8017	4.54

Total rejection due to blowholes in a year = 364
 Total production = 8017
 Rejection percentage = 4.54 %

2) Pareto analysis of blowholes

PARETO CHART FOR BLOWHOLES

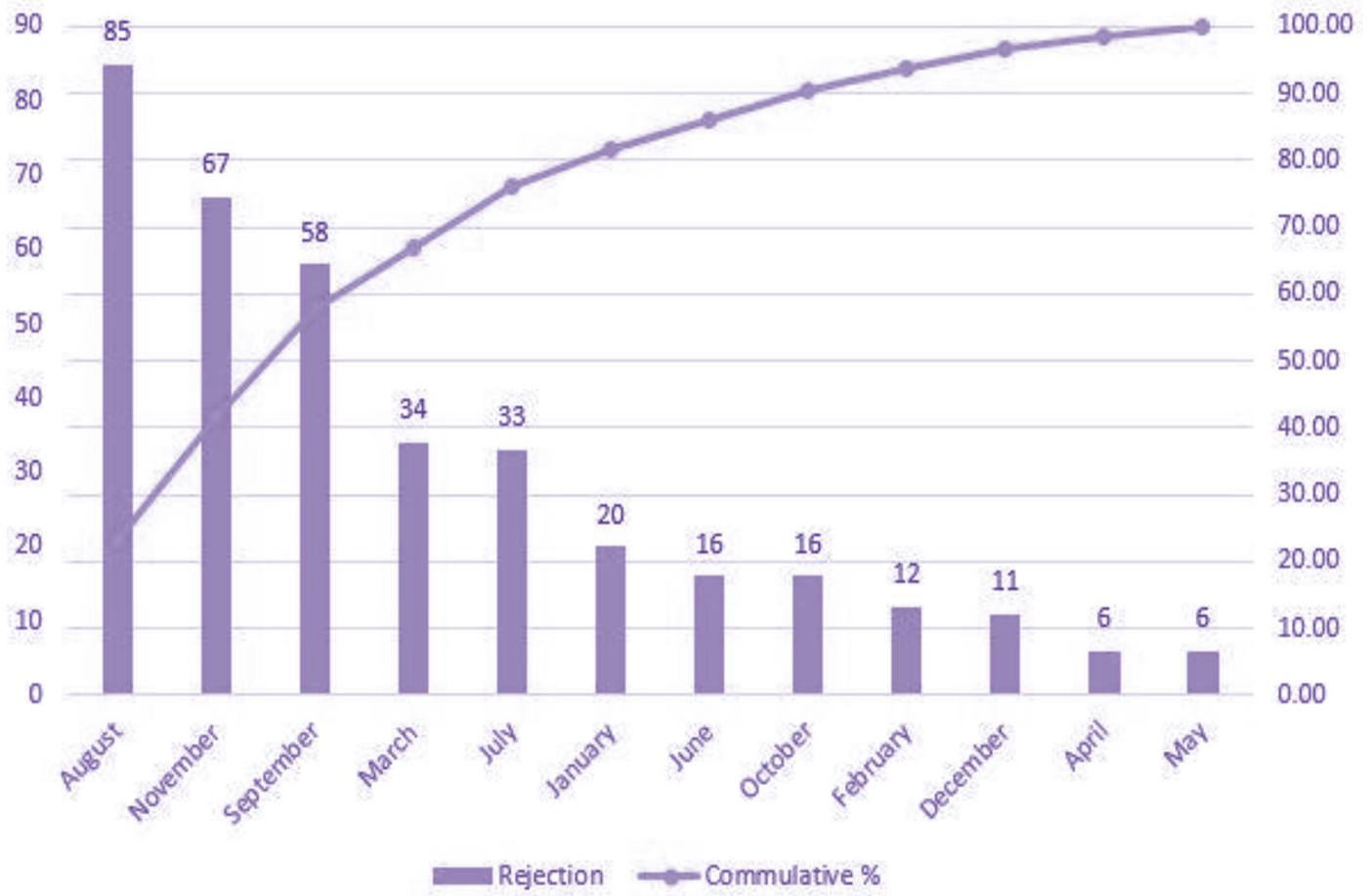


Fig. 2. Pareto chart for rejections due to blowholes

Using Pareto chart we can conclude that 80% rejections due to Blowholes occurs in the months of January, March, July,

August, September and November.

3) Fish bone diagram for blowhole:

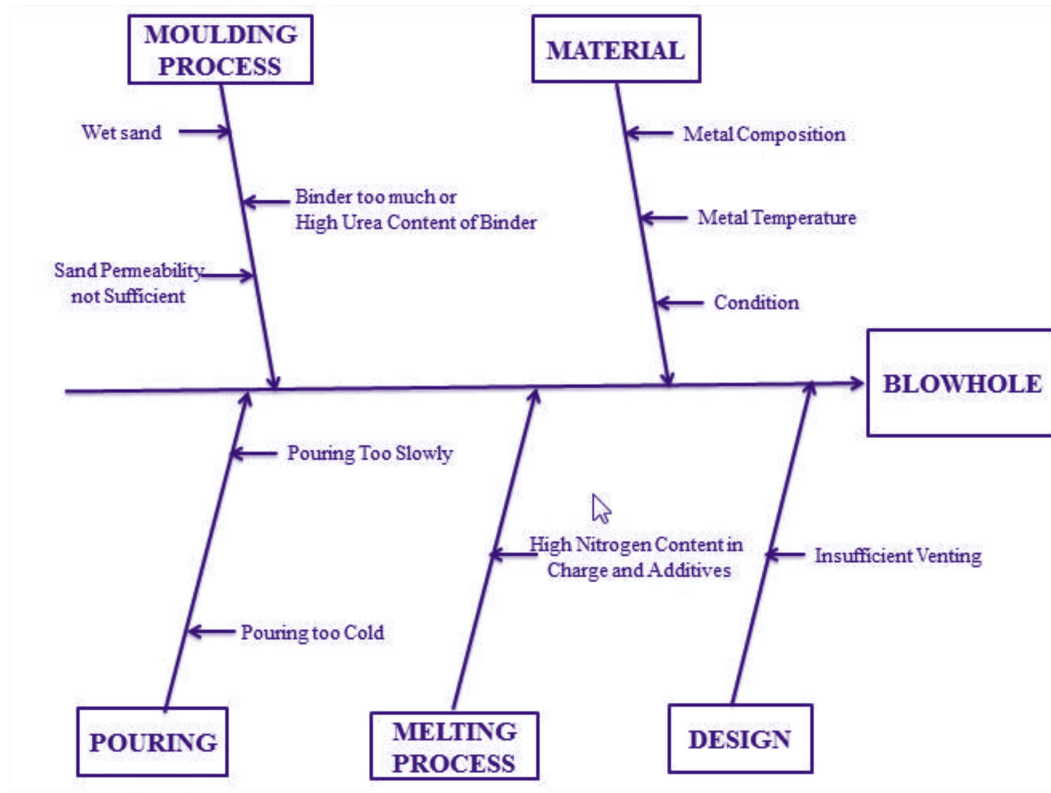


Fig. 3. Fishbone diagram for rejection due to blowholes

TABLE 5. Cause Effect Analysis For Blow Holes

Input / Process Indicator	Output
Wet Sand	9
Sand permeability not sufficient	8
Too much binder	8
Metal composition	5
Metal temperature	5
Workplace condition	5
Pouring too slow	5
Pouring too cold	5
High Nitrogen content in charge and additives	5
Insufficient venting	8

Scale:0=None, 1=Low, 5=Moderate, 9=Strong

4) Some factors responsible for blowholes in trumpet housing casting:

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

5) Solutions implemented towards wet sand: Major cause found behind blow holes was detected as wet sand in casting mold. It is because of the fact that sand contains a higher value of moisture content in it, approximately 6% - 10% it is a bit high amount of moisture content in silica sand being used for grey cast iron castings. Molding sand is dried at temperature of 105 Celsius to 110 Celsius by which time its moisture content comes

to a level about 4.3 % to 4.6%. Sand with moisture content ranging between 4.3% to 4.6% is found to have optimum working range with effective green compressible strength (GCS) and permeability. Low moisture content in the molding sand does not develop strength properties and high moisture content decreases permeability.

TABLE 6. For Comparison of Green Compressible Strength (Gcs) and Moisture with Days

Days	GCS	Moisture
1	1180	4.5
2	1165	4.4
3	1185	4.5
4	1190	4.5
5	1150	4.3
6	1000	4.4
7	980	4.5
8	985	4.3
9	1150	4.5
10	1095	4.4

The foundry is now maintaining a moisture content of

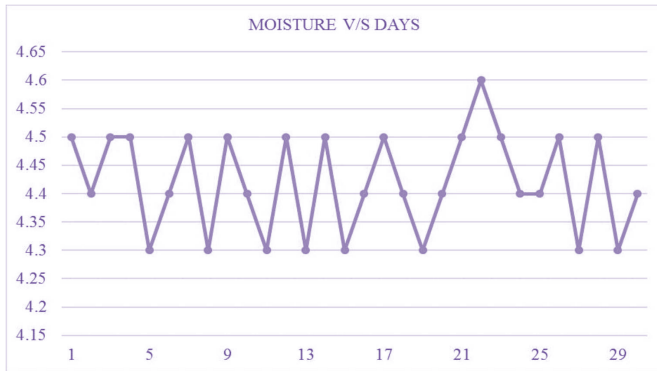


Fig. 4. Moisture v/s day's comparison

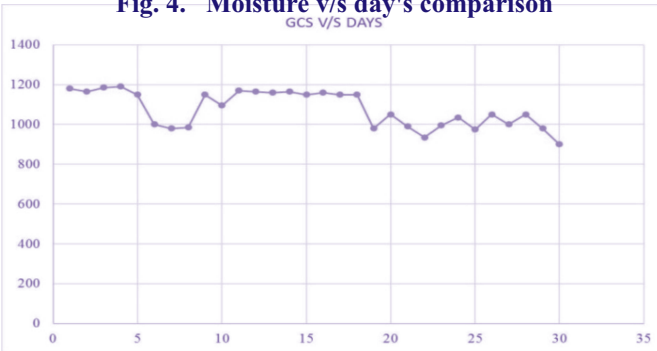


Fig. 5. GCS V/s Days Comparison

D. Detailed analysis of defect sand drop

1) Monthly rejection due to sand drop:

TABLE 7. Monthly Rejections Due To Sand Drop

Month	Rejection due to sand drop	Production per month	Rejection percentage
January	7	480	0.09
February	2	514	0.02
March	5	249	0.06
April	8	508	0.10
May	21	578	0.26
June	16	833	0.20
July	6	1129	0.07
August	12	865	0.15
September	3	835	0.04
October	5	476	0.06
November	45	1432	0.56
December	10	118	0.12
Total	140	8017	1.75

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

2) Pareto analysis of sand drop:

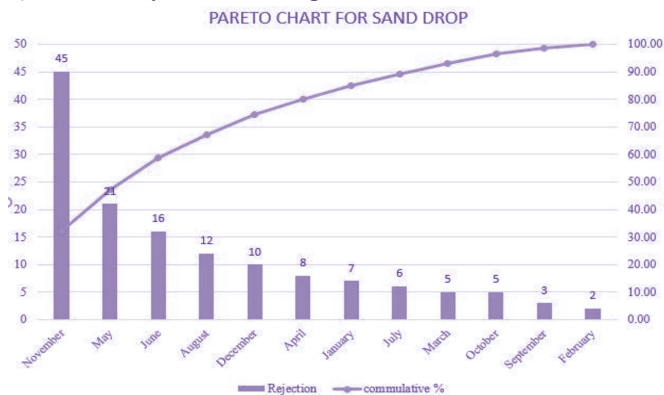


Fig. 6. Pareto Chart for Rejection Due To Sand Drop

Using Pareto chart we can conclude that 80 % of rejections due to sand drop occurs in the month of November, May, June, August, December and April.

3) Fishbone diagram for sand drop: Cause effect diagram for sand drop has been drawn and the causes for the sand drop have been studied as shown below.

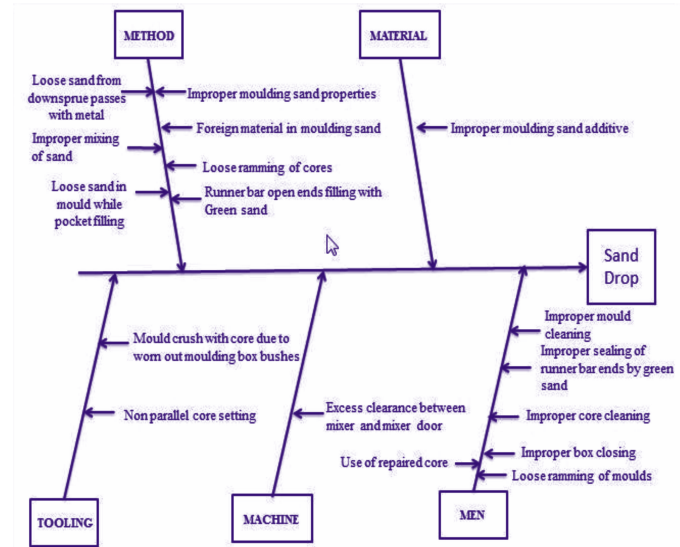


Fig. 7. Fishbone diagram for rejection due to sand drop

The five main categories used in this diagram were: Men, Method, Material, Machine and Tooling. The brainstorming session was held for finding different causes behind the Sand Drop defect and identifying the main causes those are responsible for the maximum damage. It consists of the group of members working in foundry. There are members in brainstorming session from different foundry departments which includes Lab In charge, Quality manager, Furnace supervisor, Worker. We started with Cause & Effect Analysis to find generalized reasons for Sand Drop defect.

TABLE 8. Causes & Effect Analysis for Sand Drop

Input / Process indicator	Output
Loose sand from down sprue passes with metal	8
Loose sand in mould while pocket filling	8
Improper moulding sand properties	7
Foreign material in moulding sand	7
Loose ramming of cores	7
Runner bar open end filling with green sand	5
Improper moulding sand additives	7
Improper mould cleaning	7
Improper sealing of runner bar ends by green sand	6
Improper core cleaning	5
Improper box closing	5
Loose ramming of mould	6
Use of repaired core	7
Improper mixing of sand	8
Excess clearance between mixer door and mixer	7
Non parallel core setting	5
Mould crush with core due to worn out moulding box bushes	5

Scale: 0=None, 1=Low, 5=Moderate, 9=Strong

4) responsible for sand drop in trumpet housing casting:

- Improper molding sand properties
- Foreign material in molding sand
- Improper mold cleaning
- Use of repaired core
- Improper mixing of sand
- Excess clearance between mixer door and mixer
- Loose ramming of molds

5) Solution implemented towards mixer door excess clearance:

- Mixer door adjustment to reduce excess clearance between mixer and mixer door
- Mixer design modification to increase overlap.

6) Solution implied towards improper sealed runner bar ends by operator:

- Plugging and sealing of runner bar open ends by cold box core piece
- Plugging sealing of runner bar open ends by shell core piece
- Molding line expansion to increase no of molding boxes to give sufficient cooling time.

E. Rejection data after successful implementation of solutions

TABLE 9. Revised Rejection Data of Blowholes Defect

Month	Rejection	Production per month	Rejection %
January	9	480	0.11
February	5	514	0.06
March	15	249	0.19
April	3	508	0.04
May	2	578	0.02
June	7	833	0.09
July	16	1129	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	154	8017	1.92

Total production = 8017, Blowholes = 154, % Rejection due to blowholes = 1.92

TABLE 10. Revised Rejection Data Of Sand Drop

Month	Rejection	Production per month	Rejection %
January	3	480	0.04
February		514	0.02
March	3	249	0.04
April	5	508	0.06
May	12	578	0.15
June	7	833	0.09
July	3	1129	0.04
August	6	865	0.07
September	1	835	0.01
October	2	476	0.02
November	15	1432	0.19
December	6	118	0.07
Total	65	8017	0.81

Total Production = 8017, Sand drop = 65, % Rejection = 0.81

F. Cost

1) Total revenue loss due to Blowhole before implementation of Quality Control tools was 5,38,720 and revised revenue cost reduced to 2,27,920.

- Hence total reduction in cost = 3,10,800.

2) Total revenue loss due to Sand drop before implementation of Quality Control tools was 2,07,200 and revised revenue cost reduced to 96,200.

- Hence total reduction in cost = 1,11,000.

III. CONCLUSIONS

The correct identification of the casting defect at the initial stage is essential for taking remedial actions. This study shows the systematic approach to find the root cause of a major defect in metal castings using defect diagnostic approach as well as cause and effect diagram.

- 1) Pareto diagram for defects have been drawn and the major rejections are due to Blowholes and Sand drop and it was noted that the Blowhole % decreases during the months of April and May and % increases during August to November months.
- 2) Pareto diagram for Sand drop shows that Sand drop % decreases during the months of during the months of February, March, July, September and October and increases during May, June and November months.
- 3) Cause effect diagrams have been drawn for Blowholes and major causes are taken as wet sand, too much binder, insufficient venting.
- 4) Cause effect diagrams have been drawn for sand drop and major causes are taken as Improper molding sand properties, Runner bar open end filling with green sand, Improper sealing of runner bar ends by green sand, loose ramming of mold, excess clearance between mixer door and mixer.
- 5) Blowholes reduced to 1.92% from 4.54%, in terms of revenue total saving of 3,10,800.
- 6) Sand drop reduced to 0.81% from 1.74%, in terms of revenue total saving of 1,11,000.

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