A QUALITY APPROACH TO CONTROL CASTING DEFECTS IN ALLOY WHEELS

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ABSTRACT

Whenever automotive industry grow, different alloys are being used towards improved performance and reliability. Aluminium has replaced use of many heavy metals to maintain the quality of performance, the Aluminium foundry industry has to concentrate on the quality of the products. The quality can be increased by analysing and controlling the casting defects. Aim of the current study is to study the production line of an aluminium alloy wheel manufacturing industry and to improve the quality of production using quality tools. This study is a systematic approach to control the major defects using diagnostic approach and Ishikawa diagram. Die-Casting defect analysis is carried out using techniques like historical data analysis, Ishikawadiagrams and root cause analysis. The major defects for the rejections during production were identified as shrinkages, inclusions, porosity/gas holes and cracks. Each defect is studied thoroughly and the possible causes for the defects are shown in Cause and Effect Diagrams. The molten metal temperature affects the amount of the hydrogen absorbed by it. So the effect of molten metal temperature on the specific gravity of the sample collected have been shown in a graph and the optimum value for molten metal temperature was found out.

Keywords: Diagnostic approach, Inclusion, Ishikawa diagram, Reliability, Shrinkage

I. INTRODUCTION

The study is mainly based on analysing and controlling defects in existing products. Moreover, not all products from industry are considered only alloy wheel is main concern. During the work data of one year has been analysed with the cooperation of representatives of the industry. The name of the industry has not been disclosed as a part of their protocol. This work study explores quantitative models to analyse the cause of defects. The Scope of the work of the present study is as follows:-

- To provide the industry with valuable information that they can use to plan about their products.
- To improve the productivity and quality.
- To encourage and achieve a greater level of quality in manufacturing of alloy wheel, by using database available and using it as input to future production.
- To plan production to meet customer requirements.
- To effectively correlate quality and quantity of materials for better output.

1.1 Low Pressure Die Casting

To manufacture aluminium alloy wheels, low pressure die casting method is most extensively used. The developments to manufacture castings having intricate and very thin sections are possible through low pressure die casting. The mould is made in the metal (usually cast iron/ die steel) is filled by upward displacement of molten metal from a sealed melting pot or bath. This displacement is effected by applying relatively low pressure of dry air (0.5 ~ 1.0 kg/mm2) on the surface of molten metal in the bath. The pressure causes the metal to rise through a central ceramic riser tube into the die cavity. The dies are provided with ample venting to allow air to escape, the pressure is maintained till the metal solidifies ; then it is released enabling the excess liquid metal to drain down the connecting tube back in to the bath. Since this system of upward filling requires no runners and risers, there is rarely any wastage of metal. As positive pressure maintained to force the metal to fill the recesses and cavities, casting with excellent surface quality, finish and soundness are produced. Low pressure on the metal is completely eliminates turbulence and air aspiration.

1.2 Aluminium alloy wheel manufacturing process

It consists of the following steps:

- Melting of Al Alloy
- Degassing Process
- Low Pressure Die Casting
- Solidification of Al Alloy
- X-Ray Inspection
- These steps are also shown in Figure 1.

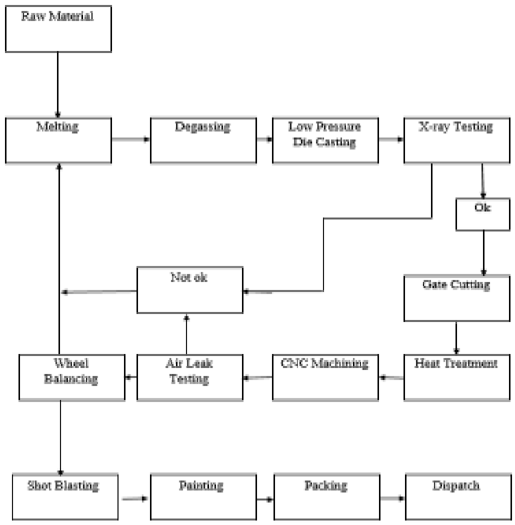

Figure 1 Process Flow Diagram for Manufacturing of Al alloy Wheel

1.3 Surface Defects

Surface defects are discontinuities occurring on the surface or near to the surface (exposed to surface) of the castings. Surface defects in aluminium die castings can result from deficiencies at any stage of the manufacturing process [16]. The prevention of surface defects is a key requirement when producing most aluminium die castings. The prevention of defects related to the casting process can best be achieved through proper design of the die and feed system and control of the variables associated with the die casting process [16]. Rowley [17] has described in detail the major surface defects of castings – gas run, cope defect, seams, flow marks and slag inclusions. Most of these defects are related to the surface of the die and temperature of the mould, and result from pouring metal that is too cold into the mould. Usually these imperfections occur in castings with relatively light sections where two surfaces of flowing metal meet and do not fuse properly. In cold shuts, small shot-like spheres of metal are almost completely distinct from the casting. This can usually be prevented by using higher pouring temperatures. Surface defects may also be related to the finishing process at the surface. Crack-like defects that emerge on the surface of a material through propagation are possible sources of failure under conditions of either stress or corrosion, or both [6].

1.4 Statistical Process Control

SPC monitors specified quality characteristics of a product or service so as to detect whether the process has changed in a way that will affect product quality and to measure the current quality of products or services. Using control charts control is maintained. The charts have upper and lower control limits and the process is in control if sample measurements are between the limits current study uses the 7 quality control tools to improve the quality of the product by minimizing the defects [42].

The most successful SPC tool is the control chart, originally developed by Walter Shewhart in the early 1920s. A control chart helps to record data so that we can see when an unusual event, e.g., a very high or low observation compared with typical process performance, occurs. Control charts distinguish between two types of process variation.

- Common cause variation: Intrinsic to the process and will always be present.
- Special cause variation: It stems from external sources and indicates that the process is out of control.

Many SPC techniques have been rediscovered in recent years like six sigma control. By integrating SPC with engineering process control (EPC) tools, which regularly change process inputs performance can be increased.

1.5 The 7 QC Tools

The 7 QC Tools are simple statistical tools used for data analysis and problem solving [43].

The following are the 7 QC Tools

Process Flow Diagram, Cause and Effect (Fishbone) Diagram, Control Charts, Check Sheet, Pareto Diagram, Scatter Plot and Histogram

1.5.1 Process Flow Diagram

It gives brief information about the relationships between the process units. It also provides knowledge about the process and identifies the process flow and interaction between the process steps. Potential control points during operation can also be identified using process flow diagram.

1.5.2 Fishbone Diagram

Once a defect, error, or problem has been identified and isolated for further study, it is necessary to begin to analyze potential causes of this undesirable effect. After identifying problem, causes for the problem should be identified. In situations like these where causes are obvious or not, the fishbone diagram (Cause effect diagram) is a useful in finding potential causes. By using Fish bone diagram, all contributing factors and their relationship with the defects are displayed and it identifies problem. So it is easy to know where data can be collected and analyzed.

1.5.3 Control Chart Analysis

Control chart analysis helps in the following ways

1. It helps in monitoring quality in the process
2. To detect nonrandom variability of the process
3. To identify assignable causes

The process is assumed to be in-control as long as the points that are plotted are within control limits, and no need to take necessary action. If a point that plots outside of the control limits we assume that the process is out of control and to take corrective action to eliminate the assignable cause. Control charts provide reducing variability and monitoring performance over time. Trends and out of control conditions are immediately detected by using control charts.

1.5.4 Check Sheets

Check Sheets are necessary to collect either historical or current operating data about the process under investigation. The check sheet is for collecting the data of defects that occur during castings. Using check sheets data collection and analysis is easy. It also spots problem areas by frequency of location, type or cause of the defect.

1.5.5 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. Pareto diagram is used in SPC and quality improvement for

1. Prioritizing projects for improvement
2. Prioritizing setting up of corrective action teams to solve problems
3. Identifying products on which most complaints are received
4. Identifying the nature of complaints occurring most often
5. Identifying most frequent causes for rejections or for other similar purposes.

1.5.6 Scatter Plot

For identifying a potential relationship between two variables Scatter Plot is used. Data is collected in pairs on the two variables, as (x, y), Then y values are plotted against the corresponding x. The relationship between the two variables can be known through the shape of the scatter plot. By using this plot, a positive, negative or no relationship between variables can be detected.

1.5.7 Histogram

It represents a visual display of data Observed frequencies versus the number of defects are given in this histogram. The height of the each bar is equal to the frequency occurrence of the defects. The shape of histogram shows the nature of the distribution of the data. On this display, the central tendency (average) and variability are seen. And also, specification limits can be used to display the capability of the process.

II PROPOSING SYSTEM

2.1 Defect Diagnostic Approach

Defect analysis in casting defects is carried out to:

- Identifying the casting defect correctly is the first step in the defect analysis [44].
- Then the identification of the sources of the defect is to be made.

- By taking the necessary corrective remedial actions defects can be controlled.
- Implementation of wrong remedial actions makes the problem complicated and severe.
- The major rejected aluminium alloy wheel castings were analyzed using "Defect diagnostic approach" as shown in Figure 2.

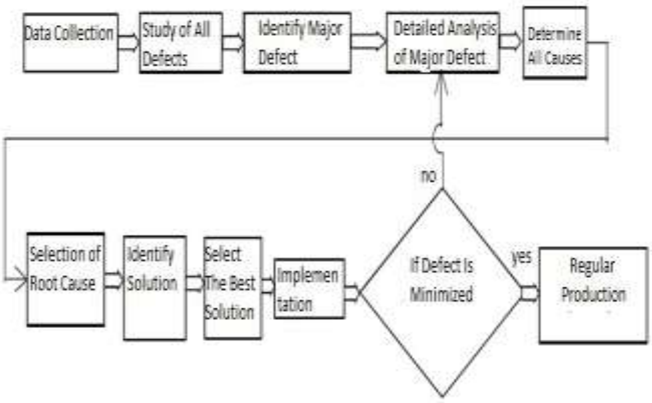

Figure 2 Defect Diagnostic Approach [3]

2.2 Historical Data Analysis

To find the rejections in castings, data for occurrence of defects for one year was collected from one of leading Al alloy wheel casting industry. Using historical data analysis [43], check sheets have been prepared which helps to identify occurrence defects in aluminium alloy castings. Using check sheets data collection is simple and it also helps in spotting problem areas by frequency of location, cause and type of defects. The details are shown in Table 1.

S.no.	Defect	Rejected Quantity	Percentage	Cumulative Percentage
1	Shrinkage	4078	38.79	38.79
2	Porosity	2610	24.83	63.62
3	Crack	1410	13.41	77.03
4	Inclusion	984	9.36	86.39
5	Unfilling	413	3.93	90.32
6	Profile Damage	194	1.85	92.16
7	Distortion	181	1.72	93.88
8	Metal Sticking	155	1.47	95.36
9	Gas Hole	122	1.16	96.52
10	Mismatch	84	0.80	97.32
11	Grinding Shade	69	0.66	97.97
12	Half Cycle	51	0.49	98.46
13	Below Range	46	0.44	98.90
14	Ejector Pin Depression	42	0.40	99.30
15	Dents	35	0.33	99.63
16	Above Range	22	0.21	99.84
17	Mesh	12	0.11	99.95
18	Without Mesh	5	0.05	100.00

Table 1 Rejection in Casting

2.3 Pareto Diagram for Defects

Using the data collected for different casting defects Pareto diagram have been drawn as shown in Figure 3

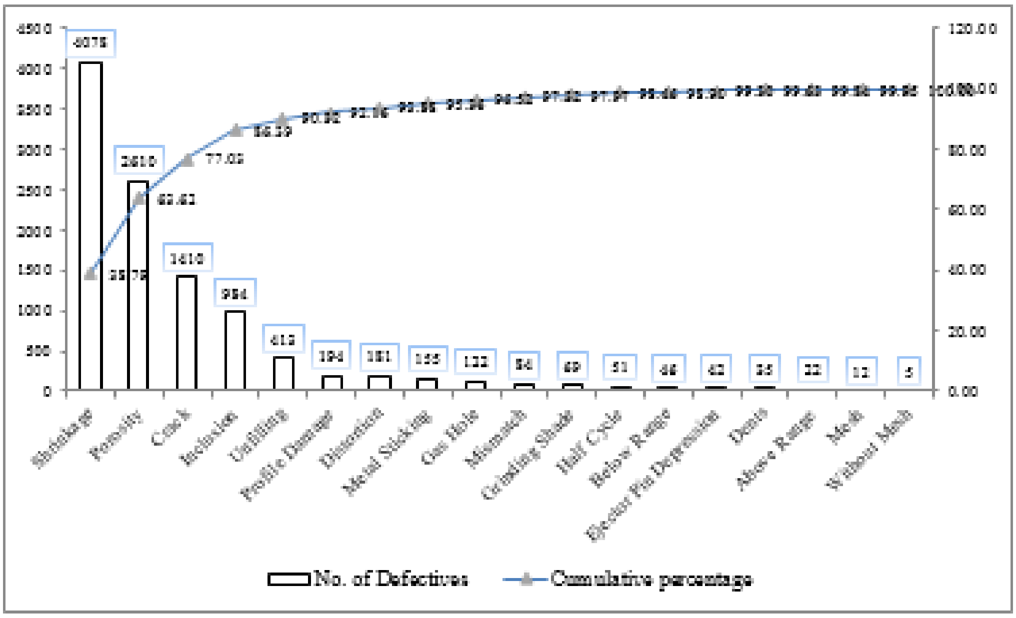

Figure 3Pareto Chart of Rejections for One Year

2.4 Shrinkages

The following points describe how shrinkages occur in castings

- Shrinkage occurs during solidification as a result of volumetric differences between liquid and solid state. For most aluminum alloys, shrinkage during solidification is about 6% by volume [46].
- Lack of adequate feeding during casting process is the main reason for shrinkage defects.
- Shrinkage is a form of discontinuity that appears as dark spots on the radiograph.
- It assumes various forms, but in all cases it occurs because the metal in molten state shrinks as it solidifies, in all portions of the final casting [47].
- By making sure that the volume of the casting is adequately fed by risers, Shrinkage defects can be avoided.
- By a number of characteristics on radiograph, various forms of shrinkages can be recognized.
- Types of shrinkages [46]
  (1) Cavity
  (2) Dendritic
  (3) Filamentary
  (4) Sponge types

2.4.1Fish Bone Diagram for Shrinkages

Fish bone diagram helps in following ways

- Once a defect has been identified, potential causes of this undesirable effect have to be analyzed.
- Fishbone Diagram (Cause Effect Diagram) is a useful tool in finding potential causes. By using this fishbone diagram, all contributing factors of defects and their relationship are displayed in a place.
- It identifies areas of problem where data can be collected and analyzed.
- The fish bone diagram for shrinkages is shown in Figure 4.

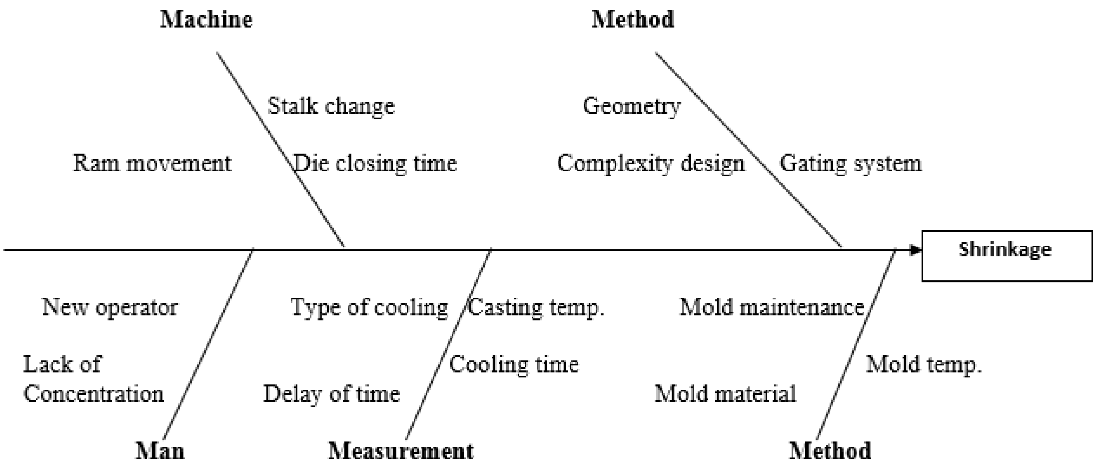

Figure 4Fishbone Diagram for Shrinkage

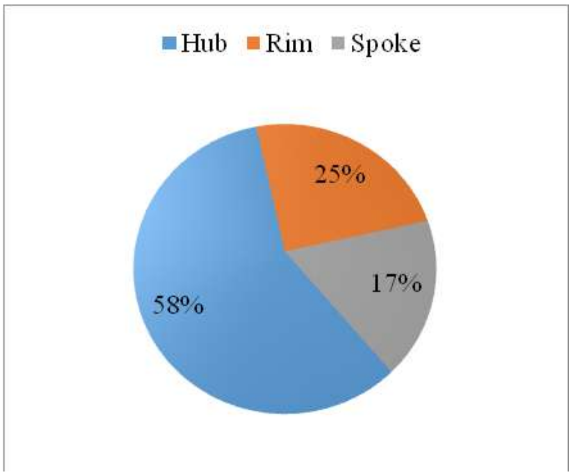

Figure 5 Pie Chart for Shrinkage

Using histogram as shown in Figure 6. It was noted that the hub shrinkages were more compared to rim and spoke shrinkages.

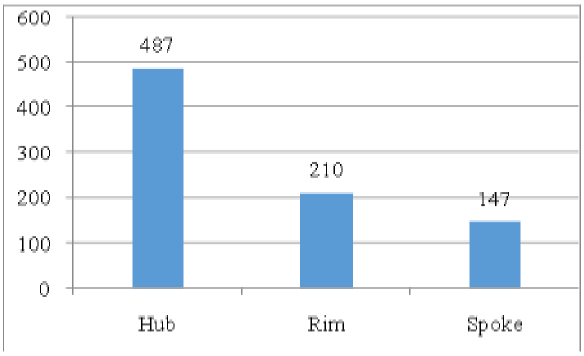

Figure 6Histogram for shrinkage defects

2.4.2Effect of Salk Change on Shrinkages

The shrinkage % and the stalk changing frequency were collected. Both are related using histogram as shown in Figure 7.

Figure 7Histogram for Stalk Change and Shrinkage

2.5 Fish Bone Diagram for Cracks

Cause effect diagram for cracks has been drawn and the causes for the cracks have been studied as shown in Figure 8.

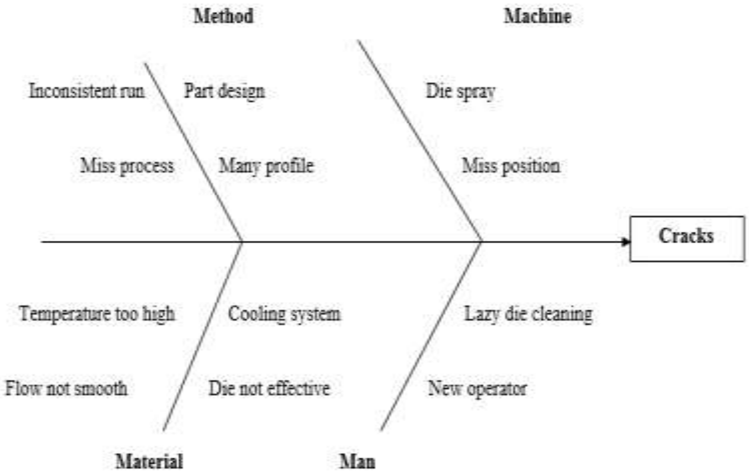

Figure 8 Cause Effect Diagram for Cracks

The effect of molten metal temperature on specific gravity of sample for different number of samples was constructed in a graph as shown in Figure 9. The change of hydrogen content in the molten metal, after the application of same degassing time, with the change of metal temperature is shown in Figure 9

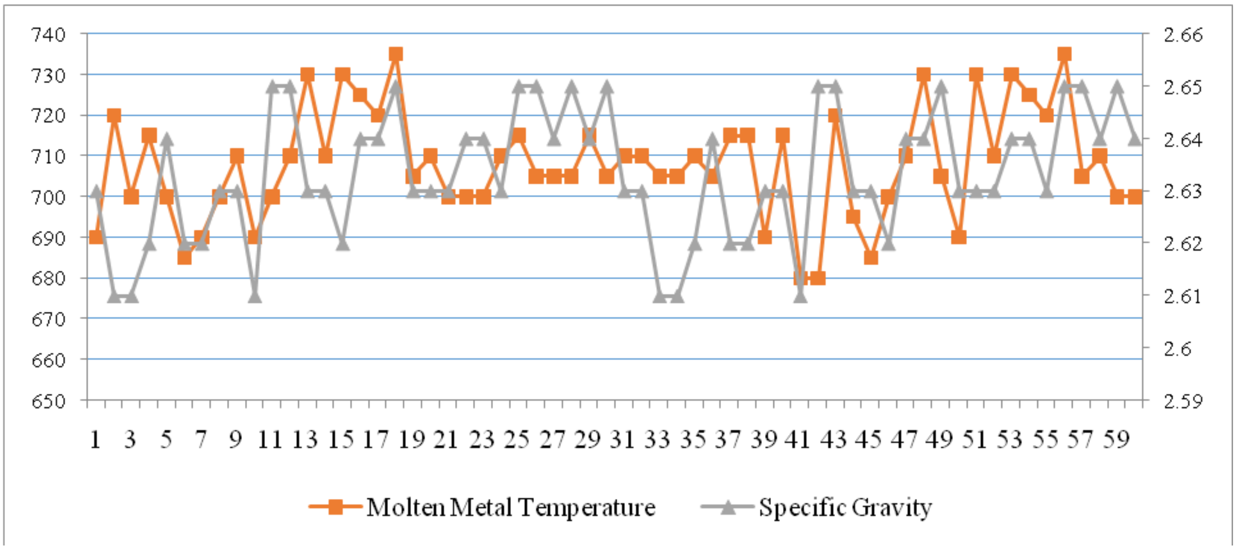

Figure 9 Effect of Molten Metal Temperature on Specific Gravity of Sample

2.6 Fish Bone Diagram for Inclusions

Fish bone diagram for inclusions is shown in Figure 10.

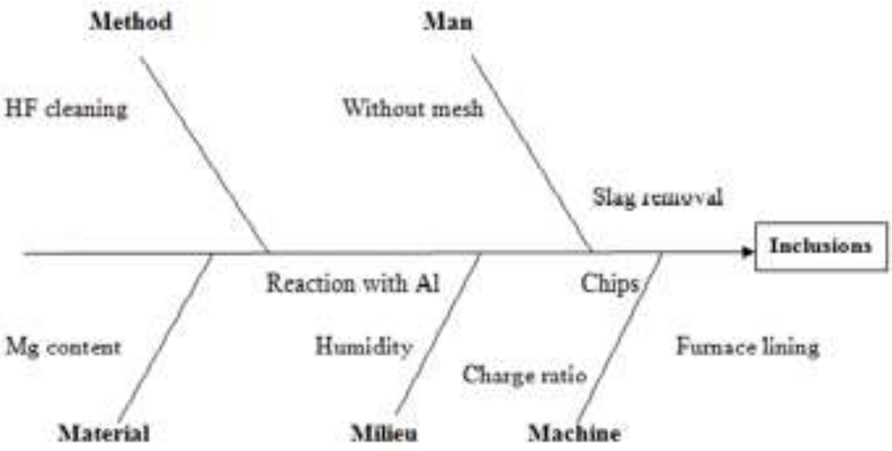

Figure 10 Fishbone Diagram for Inclusions

2.7 The Holding Furnace

Inside holding furnace (HF) molten metal can be stored and can be maintained at the required temperature. It has a charging door from which molten metal is poured into the furnace. To maintain the temperature of molten metal heaters are installed at the top of the furnace. The inclusions formed inside holding furnace are to be removed frequently to minimize the inclusions in castings. Data have been collected using check sheets and the relation between HF cleaning frequency and inclusions was plotted as shown in Figure 11.

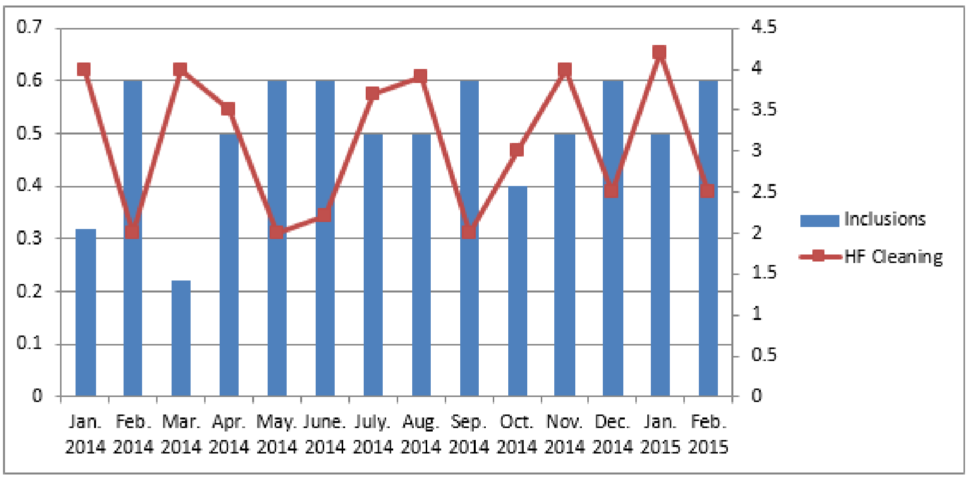

Figure 11 Inclusions vs HF cleaning frequency

III. CONCLUSION

The precise identification of the casting defects at the beginning is advisable for taking corrective and preventive actions. This study shows the intelligent and systematic approach to diagnose the root cause of a potential defects in aluminium castings using quality tools.

- Process flow diagram shows the definite processes used in the study.
- Cause and effect diagrams have been drawn for the potential causes which included shrinkages, cracks and inclusions.

- Control charts were drawn to know the behavior or the trend of upper control limit and lower control limit and how they are varying with the various defects.
- Check sheets were prepared for the authentication and validation of the data. Data has been collected using check sheets and the no of rejections due to various shrinkages have been noted. Using histogram it was noted that the hub shrinkages were more compared to rim and spoke shrinkages
- Pareto diagram for defects have been drawn and the major rejections are due to shrinkages, cracks, inclusions. Also from which defect we are supposed to start with depending upon the weightage of the defect, whether lies in 80% of the total defects.
- Scatter plot was drawn to check the dependability of one defect on the other and if one can be controlled the other was supposed to be under control.
- With the use of histograms it was noted that the shrinkage % decreases with the increase in stalk change frequency. A proper riser prevents shrinkage formation by maintaining a path for fluid flow. Therefore the feeding of the die is achieved by the effective riser.
- The relation between HF cleaning and inclusions was plotted and is concluded that there is significant decrease in the inclusions with an increase in the HF cleaning frequency. Holding furnace cleaning and removal of dross would reduce inclusions. Metal filters can be placed in gate to filter incoming molten metal.

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