International Journal of Research in Advent Technology, Vol.3, No 4, April 2015
E-ISSN: 2321-9637

Quality control and Statistical Techniques used to improve Productivity and to reduce Rejections due to Casting Defects: A Review

Vivek Patil[1], Mahesh Sutar[2]

Mechanical Engineering[1,2], U.G. Student [1], Assistant Professor[2], Annasaheb Dange College of Engineering and Technology, Ashta, Maharashtra, India.
Email: vivekpatil700@gmail.com[1], maheshsutar123@gmail.com[2]

Abstract- Casting process involves complex interactions among various parameters and operations related to metal composition, methods design, moulding, melting, pouring, shake-out, fettling and machining. For example, if shrinkage porosity is identified as gas porosity, and the pouring temperature is lowered to reduce the same, it may lead to another defect, namely cold shut. This paper introduces different techniques for reducing the casting defects and consequently the rejections. For this, one case study is performed in a foundry named Ashta Liners Ltd., Ashta, Maharashtra, India. These techniques involve Quality control as well as Statistical techniques such as Historical Data Analysis, Cause-Effect Analysis, Design of Experiments (DoE), Just-in-Time (JIT) Technique, If-Then rules (Expert System) etc. We implemented some of these techniques and we get satisfactory result in terms of reduction in rejection levels.

Index Terms- Defect Diagnostic Process, Ishikawa Diagram, DoE, JIT, SPC.

1. INTRODUCTION

Production of casting involves various processes such as pattern making, moulding and assembly, core making and melting etc. The overall casting process becomes very critical for complex parts. It is important to have a control over these casting processes to avoid casting defects like blow holes(porosity), shrinkage cavity, mis-run, hot tears etc. Such casting defects should be diagnosed correctly for appropriate remedial solution otherwise new defect may get introduced. This diagnosis is done with the help of some techniques which are mainly classified into conventional and advanced techniques. For intricate designs, conventional method does not give correct solution; hence some advanced tools are used.

In this paper, a detailed analysis of casting defects with the help of some conventional as well as modern techniques is done to get reduced rejection level. These techniques were invented in early nineties but still they are not implemented in some of the foundry industries. This research is based on the results getting by implementing some of these techniques.

The work in this paper is divided in three stages such as General procedure for analyzing casting defects, Analysis using Conventional Quality Control techniques and conclusion. Section 2 describes the general procedure for analysing casting defects which is mostly employed in foundry industries. The various methods used for reducing the defects are given in Section 3. Section 4 presents the conclusion of all the techniques explained in this paper.

2. GENERAL PROCEDURE FOR ANALYSING CASTING DEFECTS

The basic procedure for analysing the casting for defects is taking place with the help of Defect Diagnostic Approach, as shown in the figure below,

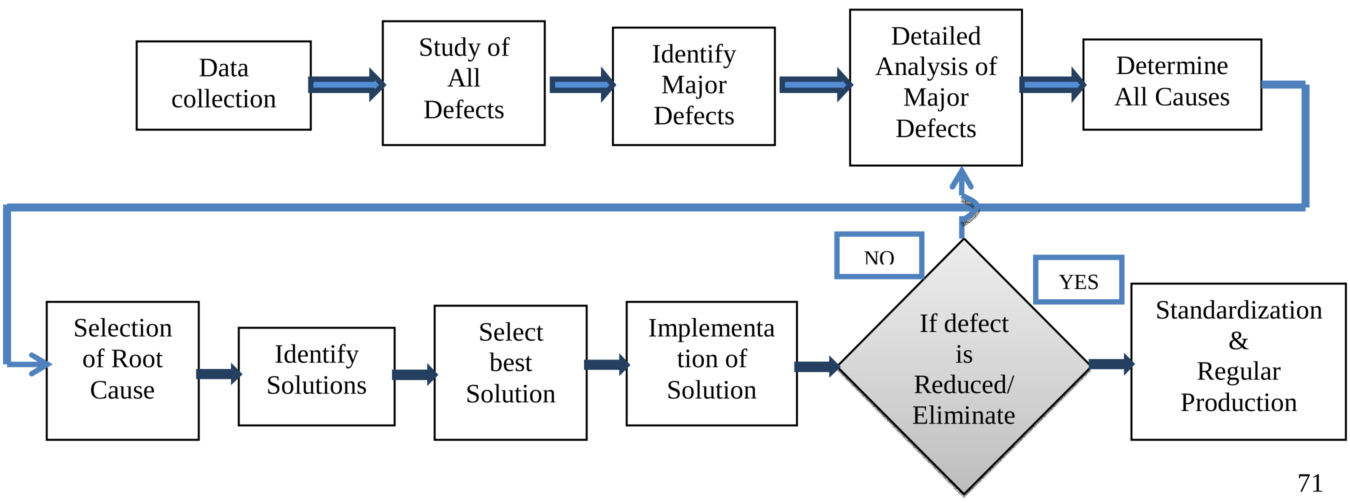

Fig. 1 Defect diagnostic process

2.1. *Preliminary study*

The study was made in a medium scale foundry producing many varieties of castings. The rejection in Rear-Cross-Over brake disc casting of Minibus (TATA) is a major problem among the many castings produced in this foundry. This major defect is analysed and solved by using the defect diagnostic approach, is presented in detail.

2.2. *Data collection*

The rejection data for a month period were collected and drawn as line graph is shown in the Fig. 2. The total rejection percentage for this casting varies from 8% to as high as 20%. The rejections were distributed to all the days of the production.

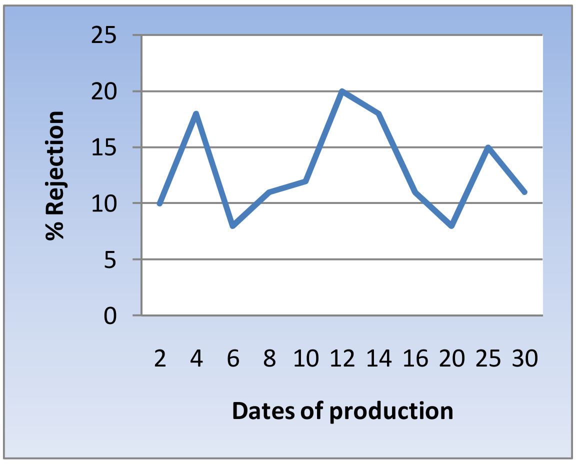

Fig. 2 Monthly production rejection data

2.3. *Study of all the defects*

The next step in the analysis is to study all the casting defects occur in the castings. The bar chart was drawn using the rejection data of the month is shown in the Fig. 3.

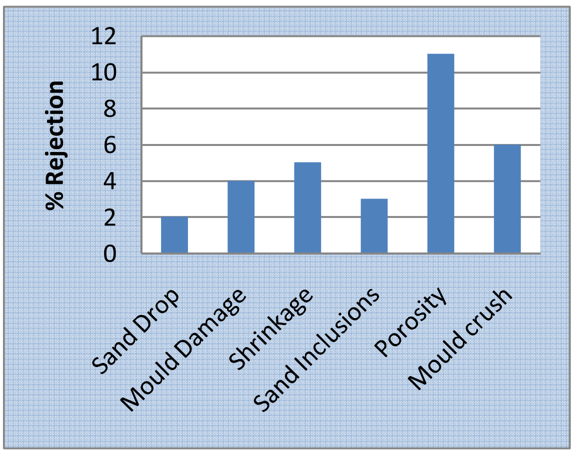

Fig. 3 Major casting defects in a month

2.4. *Identify major defect*

A Pareto chart is drawn using the rejection data of this casting is shown in the Fig. 4. It is very clear from the figure that the porosity defect is found to be the major defect among all the defects.

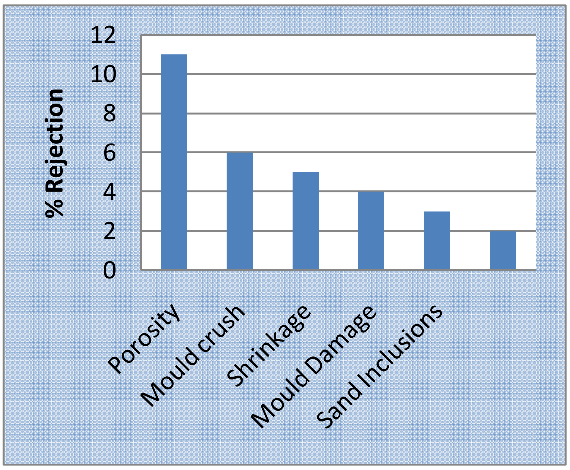

Fig. 4 Major casting defects as Pareto Chart

2.5. *Detailed analysis of the major defect*

The detailed analysis of this major porosity defect is made in this step. It is essential to know whether the porosity defect was occurring in particular days of production or it was distributed to all the days of production in the study period. A bar chart was made for this major defect for all the days of production as shown in the Fig. 5. The Fig. 5 depicts that the porosity defect was distributed over all the days of production.

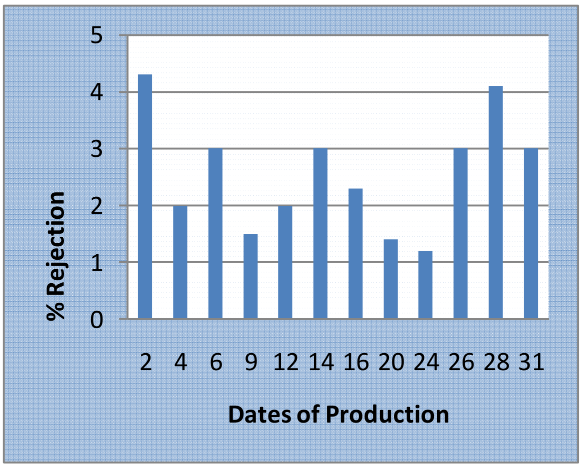

Fig. 5 Distribution of major Defects

2.6. *Determine all causes*

The porosity defect appears due to entrapped gases on the surface of casting, during solidification. Also it might be the result of irregular refinement of the grains of material during solidification. The possible causes for this defect due to various parameters and processes are found out with the help of Cause- Effect diagram. In this way root cause for the formation of porosity defect is determined.

2.7. *Selection of Root cause*

The detailed examination of rejected castings is required to identify the root cause for this major porosity defect. For reducing this defect, the proper analysis of the component is required. There are various software's are available for this purpose. The analyzed component is then simulated to get the exact location of this porosity defect. So further we found that the porosity is occurring only at the surface of the casting.

This major porosity defect can be reduced only by many ways as follows:

- By changing the material composition
- By changing the inoculation material
- By checking the mould and gating design
- By focusing on physical parameters like pouring as well as holding temperature, pouring time etc.

2.8. *Selection of the best solution*

The best solution can be selected according to the available resources.

This is one of the general methods to analyse the cast component which helps for finding the exact causes behind the defect. This further helps to find the corrective action to be taken to minimize the same defect.

3. ANALYSIS USING CONVENTIONAL QUALITY CONTROL TOOLS

[1]The conventional methods of quality control may include Historical Data Analysis, Cause-Effect Analysis, Design of Experiments (DoE), Just-in-Time (JIT) Technique, If-Then rules (Expert System) etc. The analysis using these techniques is given in below section:

3.1. *Historical Data Analysis*

As its name implies, this method is the simplest method for finding out the casting defects by using previous information about the product which we want to inspect for defects.

To understand this concept, data for occurrence of defects are collected from one of leading casting manufacturer in Maharashtra named ZANVAR Group of Industries, Ashta Liners Pvt. Ltd. Ashta,for one year. From this data, occurrence chart has been prepared which further helps to identify occurrence of major defects in castings. The details are shown in table below,

Table 1 Historical data of casting defects

Defects	**Job Rejection %**	**Defects**	**Job Rejection %**
Porosity (Surface)	6%	Mismatch	0.25%
Crush	2%	Run out	0.25%
Fettling Crack	0.75%	Low Hardness	0.25%
Shrinkage	0.75%	Bad Core	0.25%
Slag	0.3%	Knock Crack	0.2%
TOTAL	11%		

The collected data is then converted into graphical form such that the most effective parameter causing casting rejection will come at right side of the graph. Such presentation of data in terms of graph is known as "Pareto Diagram". The above data is also shown in the format of Pareto diagram as shown in figure below,

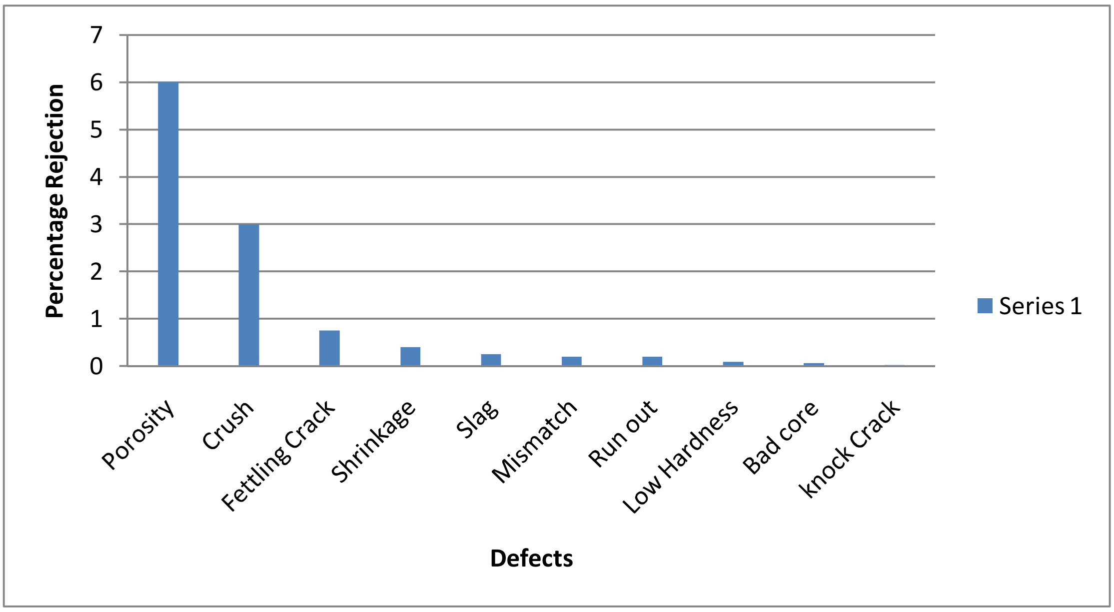

Fig. 6 Pareto analysis of casting defects

Here, Surface porosity is the most affecting factor for the casting; hence further the factors causing this defect are determined by inspecting the process of that casting and actions were taken to reduce this defect.

3.2. *Cause-Effect Diagram (Ishikawa/ Fishbone Diagram)*

Cause- effect diagram is one of the approaches to enumerate the possible causes. When all possible causes are known to us, the operating conditions are verified and applied to determine the potential cause item by item. As the primary factors are identified, they are further examined to find the specific problem that causes the defects. After the particular cause has been identified, remedies are suggested to eliminate the defects.

This diagram was invented by Japanese scientist Ishikawa and also it looks like bones of the fish, hence it is called as “Fishbone Diagram”. Example for checking the individual cause-effect for porosity defects is given below.

(Data collected for various defects occurred during sand casting for one year at Ashta Liners Pvt. Ltd., Ashta, Maharashtra)
Material: FG260 (Gray cast iron)
Casting: Rear Brake disc of Mini Bus
Production: 18000 casting /month (approx.)

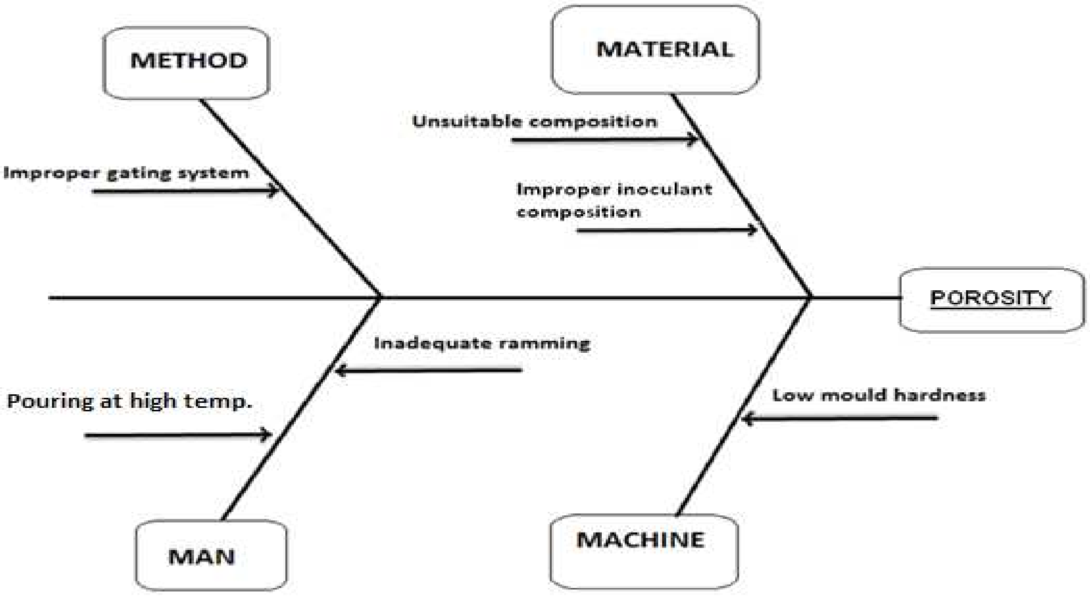

Fig. 7 Cause-effect diagram for Shrinkage casting defect

Suggested remedies are as follows;

- Use the suitable composition that is adjusted silicon (1.80 to 2.10) or carbon equivalent (3.9 to 4.1).
- Use Strontium based inoculant with Zr or Ti (Strontium=0.1% to 10%, Zr=0.5% to 10%, Ti=0.3% to 10%).
- Carry out proper ramming and maintain optimum pouring temperature and time.

3.3. *Design of Experiments(DoE)*

In casting processes, there are various parameters with different adjustment levels may influence the defects in casting. For each type of defect, several causes have been listed under differing categories such as design, moulding and pouring/melting related parameters. The focus of the design of experiment is on the robustness of the casting parameters. [3]The methodology to achieve optimized process parameters areas given below:

- Any defect is selected which is needed to be analysed. For example, many internal defects (shifts, warpage, blow holes, drop etc.) largely depends on the moulding.
- The target of process is to achieve “lower casting defects” by adjusting the process parameters.
- Select the most significant parameters that cause the defects in casting. These parameters can be identified by the cause effect diagram.
- Plan the experiments as per either design of experiments or orthogonal array (OA) and parameter levels. Based on the experimental conditions, collect the data.
- Analyse the data. An analysis of variance (ANOVA) table can be generated to determine the statistical significance of the parameters. Response graphs can be plotted to determine the preferred levels for each parameter of the process.
- Decide optimum settings of the control parameters. Verify the optimum settings result in the predicted reduction in the casting defects.

Example:

The pouring temperature and pouring time are very important parameters among the parameters affecting the casting quality. Experiments are, therefore, carried out to optimize the pouring temperature and pouring time by experiments for different types of casting. The data collected for one year from one of leading casting manufacture in Maharashtra. This data is related to the casting of Rear cross over disc of FG260 material. The optimized pouring temperature for disc is used for reduction of rejection level is as shown in figure below. Rejection level is minimum for range of 1420^0C –1440^0C.

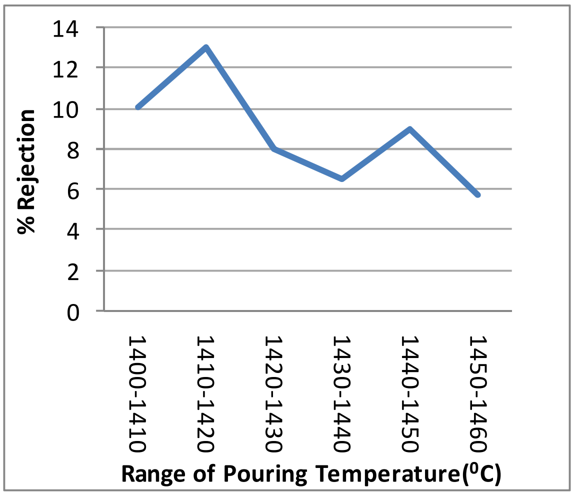

Fig. 8 Pouring temperature v/s % Rejection for Brake disc

Hence, for further production, the pouring temperature is maintained at 14200C –14400C, so the defects will be lesser and consequently rejection will be minimum.

The pouring time can also be adjusted in same manner by DoE. The pouring time is optimized for the Cast iron (FG260) Brake drum. The data collected from one of leading casting foundry at Maharashtra. The rejection level for Brake drum is minimum for pouring time of 4-6 sec.

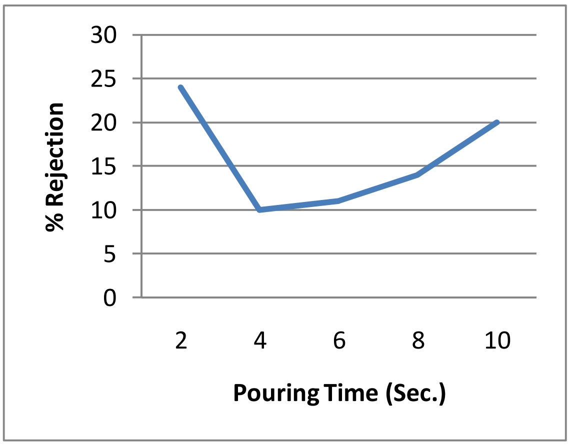

Fig. 9 Pouring time v/s % Rejection for Brake Disc

Hence, the pouring time should be maintained at 4-6 seconds to reduce the defects and also to minimize rejection rate.

3.4. *JIT Concept*

[5]There are different types of inventories according to its usefulness to the industry. From these types, unnecessary inventory (which is often termed as Waste) affects the profitability of an industry. Waste results from any activity that adds cost to the production process without necessarily adding value to the product, such as transporting

inventories from one warehouse to the other or the simple act of storing them. These wastes must be reduced to minimize the production cost and consequently to increase the profit.

Here JIT concept comes in picture. As a definition, JIT is a manufacturing philosophy that aims to eliminate waste, generating from different sources in the industries. Waste in the following areas or from the following identified sources need to be reduced or eliminated;

- Overproduction - waste from producing more than is needed
- Time spent waiting - waste such as that associated with a worker being idle when waiting for another worker to pass him an item he needs (e.g. such as may occur in a sequential line production process)
- Motion – waste associated with operator movements or employee movements on the shop-floor
- Transportation/movement - waste such as that associated with transporting/moving items around a factory
- Processing time - waste such as that associated with spending more time than is necessary processing an item on a machine
- Inventory - waste associated with keeping stocks or inventory
- Defects - waste associated with defective items

The basic concept of JIT is that the industries should produce what is needed, when it is needed and in how much quantity is needed. JIT is more than just a production and inventory planning and control system analogous to the well-known material requirements planning (MRP) systems. JIT covers all aspects of the production and inventory flow process, covering not only the work-in-process (WIP) inventories (parts), but also the flow of finished goods from manufacturing to distribution centers in the forward direction and, in the backward direction, the flow from suppliers.

The cost that saved by implementing the JIT technique can be used to employ the other methods to reduce the rejection caused by casting defects.

3.5. *Statistical Process Control (SPC)*

For reducing the defects it should be analyzed correctly. Analyzing the defect gives us information about that defect in terms of its type, location, amount of defect etc. This analysis is then used to find out the causes for generation of defects. Statistical Process Control is the technique employed for the same purpose. SPC methods can be used to analyze the data at every stage of production [Motorcu et al.] and represents that data in simple forms that can be easily readable.

SPC is made up of seven basic tools, first emphasized by Kaoru Ishikawa [Tague]. These tools are: Control Charts, Histograms, Pareto Charts, Scatter Diagrams, Fishbone Diagrams, Check Sheets, and Stratification. By using some or all of these techniques, an engineer should be able to improve the quality of final products.

The most common tool is the Control Chart, which was developed by W.A. Shewhart in the 1920's. Control Charts graph data as a function of time, where the average of the data is forming the midline and the upper and lower set limits being 3σ and -3σ respectively. These are excellent at demonstrating when process data that contains variation. Many SPC software packages can even send email alerts or sound warning alarms if the data is out of the specified range (most cases >1σ).

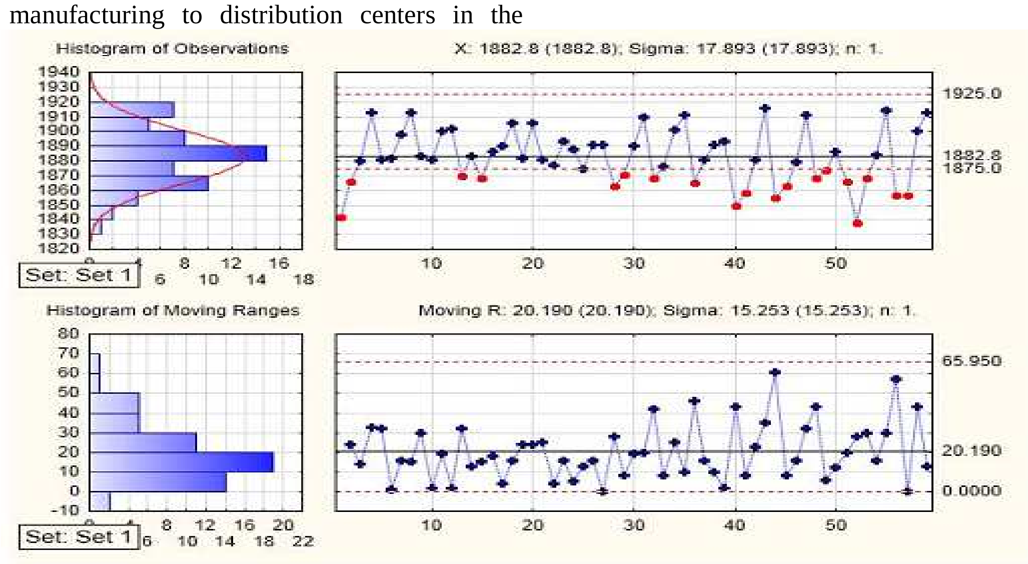

Fig.10 Histogram of different observations and relative individual and Moving Range charts (Default individual and moving range)

[6]There are various types of SPC software packages available according to their use in an industry.SPC tools can be used manually via Excel Plug-in (i.e. QIMacros) or automatically via standalone programs or SQL Server Add-Ons. The advantage of using an automatically updating system is the continuity that can be achieved. This type of SPC package would be most desirable for a general monitoring system, where perhaps the charts are displayed on a large screen so many people can see any wayward trends and start the action chain to alleviate the problem. These SPC systems can be accessed locally via a dedicated computer or remotely via a web browser (increasing in popularity).

[6]One project based on this technique was submitted by Mr. Daniel Lettiere, which indicates the use of SPC in modifying the process. They had controlled the investment casting process with the help of same technique. The data for this project is all analyzed as Individual and Moving Range graphs, due to the sampling characteristics of the datasets. By default individual and moving range charts are output as seen in the fig. 10 above.

As can be seen, this graph includes histograms of observations and a moving R chart. The graphs can be configured to remove the histograms and the moving R chart. This provides a neater, larger graph that can more easily interpreted by operators on the floor. A sample of a pure Individuals chart can be seen below in fig. 11;

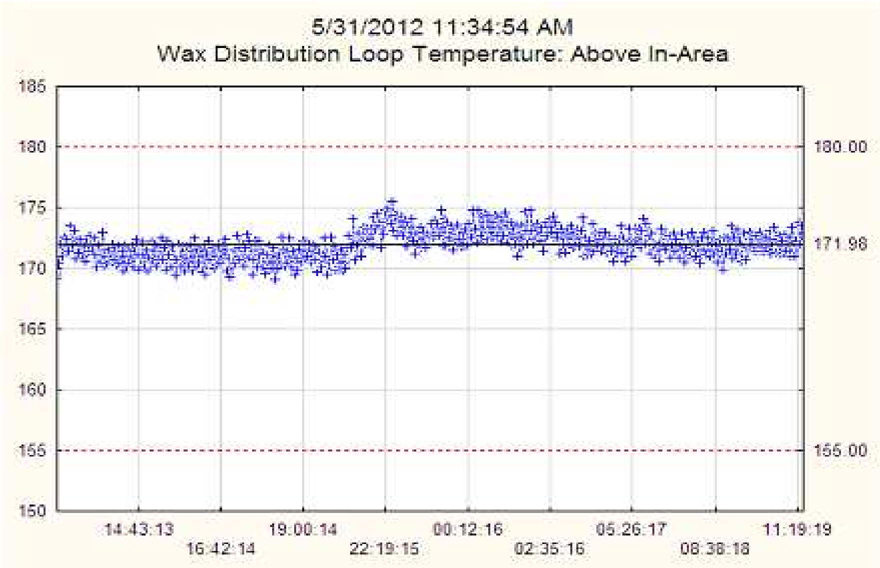

Fig.11 Pure individual chart

Hence, in this way the process data is plotted with the help of software to get the variation of process parameters in the particular process. This helps to indicate the process parameters which are out of desired limit which further helps to control those parameters.

4. CONCLUSION

We have implemented the above mentioned techniques to detect and further to reduce the rejection caused due to different casting defects. Some of the above techniques can also be implemented in small scale foundry industries to reduce the rejection levels. While some of the techniques like SPC are quite expensive to implement in a small scale industries but this method gives better results than any other technique. These techniques can be useful not only to reduce the rejection but also in various other departments in industries like inventory control, at various machines in machine shop to get process variation and to identify optimum values of parameters etc. DoE is the technique which can be implemented in any processing industry. In India there are number of small scale industries which can implement such techniques to improve the yield and increase the effective capacity of the unit. JIT is the technique that can also be implemented in any industries such as processing, design etc. and also in e-commerce and online shopping to get the things done in time. So, these techniques can be implemented in various industries with wide range of applications.

5. REFERENCES

[1] Sunil Chaudhari, Hemant Thakkar, “Review on Analysis of Foundry Defects for Quality Improvement of Sand Casting” Int. Journal of Engineering Research and Applications, ISSN :

2248-9622, Vol. 4, Issue 3(Version 1), March 2014.

[2] B. Chokkalingam, S.S. Mohamed Nazirudeen, "Analysis of Casting Defect through Defect Diagnostic Study Approach", Journal of Engineering Annuals of Faculty of Engineering Hunedora, 2009.

[3] Uday A. Dabade, Rahul C. Bhedasgaonkar, "Casting Defect Analysis using Design of Experiments (DoE) and Computer Aided Casting Simulation Technique",Elsevier Forty Sixth CIRP Conference on Manufacturing Systems, 2013.

[4] R. B. Heddure, M. T. Telsang, "Casting defect reduction using Shainin tool in CI Foundry –A Case Study", Proceedings of 8th IRF International Conference, Pune, 04thMay, 2014.

[5] IgnatioMadanhire, LovemoreKagande, Chancellor Chidziva, "Application of Just In Time (JIT) Manufacturing Concept in Aluminium Foundry Industry in Zimbabwe", International Journal of Science and Research (IJSR), India Online ISSN: 2319-7064, Volume 2 Issue 2, February 2013.

[6] Daniel Lettiere "Real-Time Process Monitoring And Statistical Process Control For an Automated Casting Facility", A Major Qualifying Project Report Submitted to the Faculty Of Worcester Polytechnic Institute, June 2012.

[7] Binu Bose V, K N Anilkumar, "Reducing rejection rate of castings using Simulation Model", International Journal of Innovative Research in Science, Engineering and Technology, Proceedings of International Conference on Energy and Environment-2013 (ICEE 2013) On 12th to 14th December Organized by Department of Civil Engineering and Mechanical Engineering of Rajiv Gandhi Institute of Technology, Kottayam, Kerala, India, Volume 2, Special Issue 1, December 2013.