A SYSTEMATIC APPROACH ON REDUCING SCRAP LEVEL USING SIX SIGMA IN INDIAN FOUNDRIES

S.Saravanakumar,
Assistant Professor-Mechanical Engineering Department, Kalaivani College of Technology, Tamilnadu, India

Abstract— In casting process various methods are involved in production like pattern designing, pattern, manufacturing, moulding, core printing, core assembly, melting, fettling, quality inspection etc. A particular cause or more number of causes may results a defect in casting manufacturing. More number of castings results in high level of rejection in castings. To reduce the scrap levels the remedial actions can be conducted in making of tools such like pattern designing, pattern making, core making and melting processes. This paper provides a systematic approach to identify and to reduce the rejection level in casting defects. If the existing defects cannot be solved then there will be a possibility for appearing a new defect(s) in casting. Maintaining rejection to bare minimum is important task to improve the productivity. The major defects were found during the study period are Air holes, Shift, cold shut and crack. To avoid these defects, necessary analysis is required to find out the root cause and the actual reason(s) to make the necessary remedial action. In this paper six sigma technique is used to identify and analysis casting defect. End result of this work has an attempt to reduce the Air holes, shift, cold shut and crack defect by taking necessary corrective action to prevent the defect.

Keywords—casting defects, six sigma

I. INTRODUCTION
The principle of manufacturing a casting involves creating a cavity inside a sand mold and then pouring the molten metal directly into the mold. Castings can unfortunately also sometimes contain other types of defects, such as inclusions of slag or molding sand, but these are not classified as solidification defects (3). The size of components is varied from very large to small, with intricate designs. Out of the several steps involved in the casting process, molding and melting processes are the most important stages. Improper control at these stages results in defective castings, which reduces the productivity of foundry industry. All foundry processes generate a certain level of rejection that is closely related to type of casting, the processes used and equipment available. However, in most foundries a substantial proportion of rejection result from lack of shop floor supervision and technical control, and the use of poorly maintained and inadequate equipment. The rejected casting can only be remelted and the value addition made during various processes such as melting, molding, fettling and heat treatment etc. is a lost irrecoverably. Casting process is also known as process of uncertainty (3). Even in a completely controlled process, defects in casting are found out which challenges explanation about the causes of casting defects. The complexity of the process is due to the involvement of the various disciplines of science and engineering with casting. The cause is often combination of several factors rather than a single one (3).During occasion of occurring the above factors also when it is appearing together the root cause of casting defect become a inscrutability. Objective of this paper to reduce the defects of casting (Air holes, shift, cold shut and Crack) by using six sigma tool.

2. LITERATURE REVIEW:
Mayank Dev et al. (5) have been focused on the flow of material movement for better utilization of plant area for improves the productivity. Objectives towards accomplished this study is to identify problems in the casting and fastening process and improved it in terms of reduction in production time. B. Chokkalingam et al. (6) has been analysis of casting defect through defect diagnostic study approach. They are presents a systematic procedure to identify as well as to analyze a major casting defect. T.R. Vijayarangam, S. Sulaiman et al. (7) have been studied Foundry quality control aspects and prospects to reduce scrap rework and rejection in metal casting manufacturing industries. Stefan H. Steiner et al. (8) studied critical overview of the Shainin System for quality improvement and provide such a review and also compare the Shainin System to other process improvement systems including Six Sigma. The fast changing economic conditions such as the severe global competition, declining profit margin, customer demand for high quality product, product variety and the need to reduce lead-time have major impact on manufacturing industries. To respond to these needs various industrial engineering and quality management strategies such as ISO 9000, Total Quality Management, Kaizen engineering, Just–in–time manufacturing, Enterprise Resource Planning, Business Process Reengineering and Lean Management have been developed. A new paradigm in this area of manufacturing strategies is Six Sigma. The Six Sigma approach has been increasingly adopted worldwide in the manufacturing sector in order to enhance productivity and quality performance and to make the process robust to quality variations (9). Reference (10) defined Six Sigma as a methodology for quality improvement. The Six Sigma concept was introduced in the early 80’s by Motorola due to two reasons. First reason was the nature of mass production and second reason was the threat of the Japanese products in the American market. It is known that a process working at 3 sigma level introduces 2600 defect per million which is not acceptable in many situations like the production of the printed circuit boards. The implementation of Six Sigma is always done using DMAIC approach [11,12,13]. In some of the above mentioned references, the five letters abbreviations are simply explained as follows;

• D: Define; what problem needs to be solved?
• M: Measure, What is the capability of the process?
• A: Analysis, When and where do defects occur?
• I: Improve, How the process capability can be improved?
• C: Control, What control can be put in place to sustain the gain?
An implementation Model for Six Sigma was applied. The model implies a top down approach were strategic decisions based on the market/customer analysis must be taken by the management (14). The model calls also for tactical decisions implying bottom up approach, where engineers or technicians are primarily involved in the decision making process in terms of the design of detailed plans to form low-level improvement teams, and the implementation, documentation, and revision of the plans’ executions. In statistics, sigma denotes the standard deviation of a set of data. It provides a measure of variability which indicates how all data points in a statistical distribution vary from the mean (average) value. For the original curve of standard normal distribution, the 3σ process with no shift (in the short term) leads to the area under the curve to be 0.99865 of the total population and the corresponding DPMO of 2700 ((15,16). The Six Sigma approach assumes a long-term process mean shift of ± 1.5σ, which leads to an area under the curve of 0.93319 and a corresponding DPMO of 66800. For the original curve of standard normal distribution, the ±6σ process with no shift (in the short term) leads to the area under the curve to be 0.9999999 and the corresponding DPMO of 0.002. The Six Sigma approach assumed a long term process to be within ± 1.5σ. This leads to an area under the curve of 0.9999966 and the corresponding DPMO of 3.4 (17). The critical success factors for any Six Sigma project implementation as mentioned in reference (18) and some of them were discussed by reference (19) include the following points which reflect the link between Six Sigma implementation and engineering management tools:

• Management involvement and commitment.
• Culture change.
• Communications.
• Organization infrastructure.
• Training as a parallel learning structure
• Linking Six Sigma to business strategy, customer, suppliers and human resources.
• Project Management skills and how it is linked to quality management
• Understanding tools and techniques within Six Sigma environment.
• Project prioritization and tools.

3. Methodology:

In the current work, one of the aims is the use of industrial engineering tools to enrich the Six Sigma methodology. This was demonstrated in using the analytic hierarchy process (AHP) method in the prioritization of the causes leading to the waste generation in the welding wire manufacturing process. The AHP method was originally developed by Thomas L. Saaty in the late 70's of the last century (20,21). Since that time, AHP is widely used for multi-criteria decision-making and has successfully been applied to many practical decision-making problems. In the AHP, the alternatives are structured hierarchically at different levels, each level consisting of a finite number of elements that may contribute to the decision making process. The relative importance of the decision elements (i.e. the weights of the criteria and the scores of the alternatives) is assessed indirectly from pair-wise comparison judgments as input to the model.

3.1. Define Phase of the Project:

The casting manufacturing process is composed mainly of the following steps. The Pattern come from the product development, pass through a molding process form the casting. The removal of molding aids will be done in fettling department. The fettled castings are then inspected for conformance then packed. SIPOC is an acronym standing for supplier, input, process, output, and customer. It refers to the technique of analyzing a process relative to these parameters to fully understand their impacts. A SIPOC diagram for the casting manufacturing process is given in Table 1.

<table>
<thead>
<tr>
<th>Supplier</th>
<th>Input</th>
<th>Process</th>
<th>Output</th>
<th>Customer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product Development</td>
<td>Pattern</td>
<td>Pattern Making</td>
<td>Pattern with required design</td>
<td>Molding and core making</td>
</tr>
<tr>
<td>Molding and core making</td>
<td>Pouring molten metal</td>
<td>Solidifying the molten metal at room temperature</td>
<td>Casting with molding aids</td>
<td>Fettling &amp; Heat treatment</td>
</tr>
<tr>
<td>Fettling &amp; Heat treatment</td>
<td>Heat treatment, Shot blasting</td>
<td>Heat treating and removing sand</td>
<td>Finished rough part</td>
<td>Quality control</td>
</tr>
<tr>
<td>Quality</td>
<td>Drawing with Dimension s</td>
<td>Checking the casting dimensions for drawing</td>
<td>Whether to accept or reject</td>
<td>Machine shop for further actions</td>
</tr>
</tbody>
</table>

In the first phase—the Define phase—of the current Six Sigma (DMAIC) process there were four main steps implemented as follows:
(1) Investigation of the Company Processes & Work Environment
(2) Drafting the Supplier, Input, Process, Output, and Customer (SIPOC) Diagram.
(3) Collecting Preliminary Data  
(4) Writing Problem Definition Statement

As a part of the define phase of the Lean Six Sigma methodology, historical preliminary data was collected to define the size and nature of the existing problems. The records of the scrap (Rejection / Rework / Concession Summary (Foundry C.I)) were collected as given in Table 2.

**TABLE 2. SCRAP LEVEL DURING JAN’14 - DEC’14**

<table>
<thead>
<tr>
<th>S.No</th>
<th>Month</th>
<th>Prod Qty</th>
<th>Rej Qty</th>
<th>Scrap Qty</th>
<th>Reason(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Jan’14</td>
<td>387</td>
<td>158</td>
<td>42.77</td>
<td>Air Holes, Crack, Shrinkage</td>
</tr>
<tr>
<td>2</td>
<td>Feb’14</td>
<td>1208</td>
<td>129</td>
<td>11.00</td>
<td>Air Holes, Shrinkage</td>
</tr>
<tr>
<td>3</td>
<td>Mar’14</td>
<td>6611</td>
<td>729</td>
<td>13.42</td>
<td>Air Holes, Shift, Shrinkage</td>
</tr>
<tr>
<td>4</td>
<td>Apr’14</td>
<td>7789</td>
<td>996</td>
<td>14.63</td>
<td>Air Holes, Cold Shut, Shrinkage</td>
</tr>
<tr>
<td>5</td>
<td>May’14</td>
<td>13482</td>
<td>1438</td>
<td>22.89</td>
<td>Air Holes, Shift</td>
</tr>
<tr>
<td>6</td>
<td>Jun’14</td>
<td>10459</td>
<td>1687</td>
<td>20.54</td>
<td>Air Holes, Hardness</td>
</tr>
<tr>
<td>7</td>
<td>Jul’14</td>
<td>5497</td>
<td>611</td>
<td>8.79</td>
<td>Air Holes, Hardness, Shrinkage</td>
</tr>
<tr>
<td>8</td>
<td>Aug’14</td>
<td>2841</td>
<td>436</td>
<td>18.77</td>
<td>Air Holes, Cold Shut, Shrinkage</td>
</tr>
<tr>
<td>9</td>
<td>Sep’14</td>
<td>4366</td>
<td>523</td>
<td>13.48</td>
<td>Air Holes, Shift, Shrinkage</td>
</tr>
<tr>
<td>10</td>
<td>Oct’14</td>
<td>217</td>
<td>38</td>
<td>16.88</td>
<td>Air Holes</td>
</tr>
<tr>
<td>11</td>
<td>Nov’14</td>
<td>1123</td>
<td>63</td>
<td>14.86</td>
<td>Air Holes, Shift, Shrinkage</td>
</tr>
<tr>
<td>12</td>
<td>Dec’14</td>
<td>2751</td>
<td>201</td>
<td>15.28</td>
<td>Air Holes, Cold Shut</td>
</tr>
</tbody>
</table>

The %42.77 waste in the month Jan’14 was taken as the base month to study and compare the subsequent months’ improvement efforts done by the factory towards a target waste of less than or equal 2% of the total input material.

### 3.2. Measure Phase:

The second phase of the DMAIC process is the Measure phase, the following our processes were performed during the study.

1. Process Mapping  
2. Data Collection  
3. Sigma level calculations  
4. Down Time Measurements

In order to have a detailed understanding of the different processes in the casting manufacturing process and their relationships, the process map as one of the tools of Lean Six Sigma (LSS) was used. The process map highlights the different areas where the waste may be generated. Studying the process elements revealed that there are five main types of waste namely; Shrinkage, Air Holes, Shift, Crack, and Cold Shut. The breakdown of the different waste types generated in year 2014, which was taken as the base year for improvement. In this phase the criticality of each type of waste shall be analyzed. A Pareto chart as one of the tools of Lean Six Sigma methodology was used to display the criticality of each waste type as shown in Figure 2. According to the collected data through out a year, the annual waste ratio was 18 % of total annual input material, and the calculated yield was 95.75%. The yield calculations are displayed below.

**Fig.3. Fish bone Diagram**

The 80-20 rule was used to distinguish the sub-causes that have the most weighted on waste generation using the Pareto chart. The rule showed that, there are six sub-causes that account for %80 of the waste generation as follows: (1) Old age of equipment  
(2) Process breakdown due to lack of raw materials  
(3) Poor control of sand mixing at moulding area  
(4) Poor maintenance planning  
(5) Number of reclaiming machines not sufficient  
(6) Not clean working area

These causes were considered in the improve phase of the Lean Six Sigma process to be addressed for possible improvement according to the available company resources.

### 3.5. Improve Phase:

In this stage the improvement actions can be applied towards reducing the waste level in company were:

1. Monthly waste monitoring and reporting to be implemented for the purpose of keeping the waste below 2 % as per design specifications.
2. A new control panel can be installed for the drawing and cutting machines instead of the previous panel of poor condition as a countermeasure for the old fashion equipment.
3. A contract with a new supplier for pattern making was established and materials were received from that supplier as a countermeasure for the lack of raw material cause.
4. The sand mixing machine was replaced by a new one with accurate control system to have a highly reliable measuring
and mixing system as a countermeasure for the poor control of sand mixing.

(5) Complete maintenance program can be implemented in the production line. This came as a countermeasure for the poor maintenance planning problem.

(6) As a countermeasure for the not clean working area problem, the cleaning process of the work area was promoted by implementing a daily schedule of cleaning with a check list containing the name of the responsible worker, the area and the machines to be cleaned as well where his signature.

(7) Restricted instructions for engineers to avoid having any unpacked products were also implemented to avoid generating more waste due to bad storage.

The results indicated that, for the year of 2014 the calculated yield was 87.65%, from this yield, the sigma level was calculated and found to be 2.7 corresponding to DPMO of 123,548.0. Using the company’s target of 2% waste, the target sigma level was calculated to be 3.55 leading to DPMO of 17,600.

After applying the LSS methodology the yield after the improvement efforts reached 98.24% corresponding to a sigma level of 3.6 and DPMO of 17,600.

### Accomplished Recommendations

<table>
<thead>
<tr>
<th>Accomplished Recommendations</th>
<th>Planned Actions for Control</th>
<th>Frequency</th>
<th>Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>A contract with a new supplier for steel wire was established</td>
<td>Evaluation for all suppliers</td>
<td>Three months</td>
<td>Purchasing Department</td>
</tr>
<tr>
<td>Mixing machine replaced by a new one with a more reliable counter.</td>
<td>Predictive and Preventive maintenance as per manuals</td>
<td>Weekly</td>
<td>Maintenance Department</td>
</tr>
<tr>
<td>Complete maintenance was implemented to the drawing and cutting machine</td>
<td>Predictive and Preventive maintenance as per manuals</td>
<td>Weekly</td>
<td>Maintenance Department</td>
</tr>
<tr>
<td>Cleaning process of the work space</td>
<td>Set schedule for cleaning with a checklist and signature</td>
<td>Daily</td>
<td>Production Department</td>
</tr>
<tr>
<td>Instructions for engineers to avoid having unpacked products</td>
<td>Ensure that there is no unpacked product</td>
<td>Daily</td>
<td>Production Department</td>
</tr>
</tbody>
</table>

4. Conclusions

The above methodology can be implemented (DMAIC) in the casting company. The tools of the Lean six sigma methodology enhanced the efforts towards scrap level reduction. The 80/20 rule of the Pareto analysis is used to identify the most important cause of waste. The ultimate aim of the organization is to reduce scrap level to below 4% which cannot be the possible one by neglecting the follow up of a systematic methodology like Lean Six Sigma (LSS). LSS is imparted towards achieving the scrap level then the company objective will be fulfilled.

### References

[1] R. B. Heddire, M. T. Telsang casting defect reduction using shainin tool in cifoundry—a case study, 8th irf international conference, 04th may-2014, pune, india, isbn: 978-93-84209-12-4


