Analysis and Minimization of Blow Holes using DMAIC Approach

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Abstract— The present work deals with minimization of sand casting defects in a foundry industry. DMAIC approach is justified when root cause of defect is not traceable. At present, global and competitive environment, foundry industries need to perform efficiently with minimum number of rejection in their manufacturing products. For better improvement in the casting quality, first of all finding the root causes of occurrence of defects blow hole in the casting process and taking necessary step to reduces defects and hence rejection in casting. Six sigma is more than a quantitative statistical measure of processes; it embraces every aspect of work, using a disciplined, fact based approach of problem-solving. Many time defects occur due to variation in the process parameter which are very difficult to detect. In the present work the metal casting process is analysis and minimised by using DMAIC (Define, Measure, Analysis, Improve, and Control) approach. Through a case study in a medium scale foundary, the present work formulate a comprehensive strategy of six sigma in indianfoundary. This study has significantly increase the efficiency of foundry industry and reduce scrap and waste in sand casting process which improve the production efficiency. A number of experiments are carried out to validate the results which indicate that the cost of experimentation will be less, in comparison to the gain or profit of the company. The results achieved shows that the rejection due to blow hole defects has been reduced from 5.83% to 2.04% which saved the cost of Rs 23828/- monthly (for continuous four months), in a turnover of 60 lakhs.

Key words: DMAIC, Define Phase for Blow Holes

I. INTRODUCTION

Present study was done at SWASTIK INDUSTRIES KAITHAL, HARYANA on application of Six Sigma methodology and Selection of tools and techniques for problem solving, because the rejection rate is very high.

The present case study deals with reduction of rejection due to casting defects in a foundry industry. The industry is making cast iron castings of submersible pumps components such as Upper housing, Motor Pulley, Mini Chaff cutter wheel, Hand wheel in large scale and having rejection in the form of Blow hole, Misrun, and slag inclusions.

The DMAIC is both a philosophy and a methodology that improves quality by analyzing data, to find root cause of quality problems and to implement controls. Although DMAIC implemented to improve manufacturing and business, processes such as product design and supply chain management. It is a business improvement strategy used to improve profitability to drive out waste in business process and to improve the efficiency of all operation that meet or exceed customer’s needs and expectation. DMAIC is a customer-focused program where cross functional teams works on project aimed at improving customer satisfaction.

II. LITERATURE REVIEW

The basic concept behind the DMAIC approach is to reduce product and process variation and conducted a case study at carriage and wagon works. Rejection statistics of axle were collected and critical causes were identified for corrective actions. Then, suggestions were implemented and rejections thereafter collected and compared with the previous rejections and found there were considerable improvements. The results achieved were demonstrated using Pareto diagrams and it was found that 5.9% of rejections were reduced.[14] The (DMAIC) quality technique was first applied in manufacturing operations and rapidly expanded to different functional areas such as marketing, engineering, purchasing and servicing. The company Whirlpool has increased its quality by 10% by adopting DMAIC technique.[12] DMAIC is a quality improvement process which solves customer problems. It is a way to focus employees on quality and establishing a common language across the company. It also creates clearly defined performance goals.[13] The study on implementing DMAIC based six sigma approaches in order to reduce defects and increase six sigma levels in sand casting process. They defined step by step guide using DMAIC, which describes overall decline of defect rejection and in process, sigma level increased 3.32 to 3.47.[11]

III. PROBLEM FORMULATION

All processes the smallest variation in quality of raw material, operator behavior, production conditions and other factors can result in a cumulative variation (defects) in the quality of the finished product. DMAIC approach aims to eliminate these variations and to establish practices resulting in a consistently high quality product. Therefore, a vital part of DMAIC work is to define and measure variation with the intent of discovering its causes and to develop efficient operational means to control and reduce the variation. The expected outcomes of DMAIC efforts are faster and more robust production development, more efficient and capable manufacturing processes, and more confident overall business performance.

The complete data of all three defects are shown in table 1, 2 and 3 for upper housing, motor pulley and mini chaff cutter respectively shows that the rejection due to blow holes is very high. So it is very necessary to take some action to minimize the defect in these parts.

A. Define Phase for Blow Holes:

These are smooth walled rounded, flattered or elongated cavities in the castings. When these cavities holes inside the casting are known as Blow holes. As shown in fig.1. These are caused moisture left in the mould and core. Because of the heat of molten metal moisture is converted into steam and entrapped inside the casting, which and up as Blow holes.
B. Measurement Phase for Blow Holes:

First to collect the data of rejection in blow holes. The data collected four months and find out the defects in Blow holes. I have collected four months data in industry. I found that the rejection in blow holes is 8.46% for upper housing and total data for upper housing is given below in table 1, the rejection in motor pulley is 7.63% is given in table 2 and rejection in Mini Chaff cutter wheel / hand wheel is 5.18% is given in table 3.

<table>
<thead>
<tr>
<th>Month</th>
<th>Production Pieces of upper housing</th>
<th>Rejection Pieces</th>
<th>Blow holes defects</th>
</tr>
</thead>
<tbody>
<tr>
<td>May.2014</td>
<td>540</td>
<td>108</td>
<td>47</td>
</tr>
<tr>
<td>June.2014</td>
<td>515</td>
<td>102</td>
<td>42</td>
</tr>
<tr>
<td>July.2014</td>
<td>525</td>
<td>106</td>
<td>45</td>
</tr>
<tr>
<td>Aug.2014</td>
<td>512</td>
<td>99</td>
<td>43</td>
</tr>
<tr>
<td>Total</td>
<td>2092</td>
<td>415</td>
<td>177</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Month</th>
<th>Production Pieces of hand wheel</th>
<th>Rejection Pieces</th>
<th>Blow holes defects</th>
</tr>
</thead>
<tbody>
<tr>
<td>May.2014</td>
<td>5034</td>
<td>837</td>
<td>256</td>
</tr>
<tr>
<td>June.2014</td>
<td>5042</td>
<td>846</td>
<td>264</td>
</tr>
<tr>
<td>July.2014</td>
<td>5040</td>
<td>833</td>
<td>259</td>
</tr>
<tr>
<td>May.2014</td>
<td>5045</td>
<td>847</td>
<td>267</td>
</tr>
<tr>
<td>Total</td>
<td>20161</td>
<td>3363</td>
<td>1046</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Defects</th>
<th>No. of defective pieces</th>
<th>Percentage of rejection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blow holes</td>
<td>1539</td>
<td>5.83%</td>
</tr>
</tbody>
</table>

But the overall percentage of rejections has been found as below.

Total production of three parts in four months = 26393
Total rejection pieces due to blow holes = 1539
Overall rejection percentage = 1539/26393*100 = 5.83%

It is clear that the overall rejection is very high. So it is very necessary to reduce the rejection in three parts.

IV. ANALYZE PHASE FOR BLOW HOLES DEFECTS

Find out the causes for Blow holes & draw the problem with the help of fishbone diagram 7.

This fig. shows that factor affecting and region for blow hole defects.

A. Cause for Blow Holes:
   - Excess moisture in molds or cores.
   - High moisture content of mould.
   - Insufficient evacuation of air and gas from the mold cavity.
   - Insufficient mold and core permeability.
   - Low permeability of moulding sand.

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   - Insufficient mold and core permeability.
   - Low permeability of moulding sand.
B. Cause-And-Effect Analysis Tool:
A cause-and-effect, or fishbone, diagram depicts potential causes of a problem. The problem (effect) displays on the right side and the list of causes on the left side in a treelike structure. The branches of the tree are often associated with major categories of causes. Each branch has a listing of more specific causes in that category. Although there is no "correct" way to construct a fishbone diagram, some specific types lend themselves well to many different situations.

After that Brain storming Sessions were conducted with Key members of industries from where root causes for the problem was taken out for further analysis. The root factor which has been found to be affecting this defect is:
For blow Holes
1) High moisture content
2) Low permeability

V. SAND CONTROL TESTS
After mapping the process AFS number of sand is found out by performing sieve analysis. In AFS sieve analysis size and distribution of sand grain in sand is determined.

A dried 50 kg sand sample is used. The sample is placed on the top of sieve and shaken for 10 minutes. After shaking, the sand retained on each sieve and bottom pan weighted and its percentage of total sample determined. The fig. 4 shows a sieve testing machine which are used for sieve analysis of sand.

B. Permeability Test:
In the Permeability test firstly the sand is poured in to the same apparatus which is used for testing the compatibility then after ramming three times the sand container is kept on permeability testing equipment and reading dial shows permeability. Permeability is expressed in term of permeability number which is defined as the volume of air in cc that will pass per minute through a sand sample of 1cm$^2$ in cross section and 1 cm in height at a pressure of 1gm/cm$^2$. The fig. 6 shows the equipment for permeability test.

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For blow Holes
1) High moisture content
2) Low permeability

Following test were conducted to check whether the sand characteristic as per specifications.

A. Moisture Content Test:
In the moisture content test weighted amount of sand sample and calcium carbide are placed in two containers and allowed to mix by shaking the container. The resulting pressure of gas generated is indicated on the scale which is calibrated directly in the percentage of moisture and moisture was recorded 7.26%. The fig. 5 shows amoisture testing machine which are using ultra violet lamp drier for moisture content testing of sand.

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VI. IMPROVE PHASE FOR BLOW HOLES DEFECTS
These are the following improvement which is given below.
A. Improvement in Blow Holes Defects:
The root factors for blow holes defects were high moisture and low permeability. The industry was using 100% of reuse sand. After performing the test with 100 kg of sand sample, it was found that percentage of moisture was high and percentage of permeability was low. Therefore to reduce the blow holes defects it was necessary to increase the percentage of new silica sand to reduce the moisture and adding the permeability. The different results have been obtained by adding the new silica sand as below.

Moisture content has been reduced in the sand by adding new sand from 5% to 6.5%. So these results in reduction of moisture contact and permeability have been increased as shown in table 5. After testing the sand the following results were obtained which were in comparison with the standard results towards achievements of reduction of sand casting defects.

<table>
<thead>
<tr>
<th>S.N</th>
<th>Addition of new silica sand</th>
<th>Moisture</th>
<th>Permeability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5 %</td>
<td>5.74 %</td>
<td>138 cc / min</td>
</tr>
<tr>
<td>2</td>
<td>5.5 %</td>
<td>5.06 %</td>
<td>159 cc / min</td>
</tr>
<tr>
<td>3</td>
<td>6 %</td>
<td>4.68 %</td>
<td>176 cc / min</td>
</tr>
<tr>
<td>4</td>
<td>6.5 %</td>
<td>3.82 %</td>
<td>188 cc / min</td>
</tr>
</tbody>
</table>

Table 5:

<table>
<thead>
<tr>
<th>Month</th>
<th>Production pieces</th>
<th>Rejection Pieces</th>
<th>Blow holes defects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nov.2014</td>
<td>546</td>
<td>37</td>
<td>15</td>
</tr>
<tr>
<td>Dec.2014</td>
<td>548</td>
<td>41</td>
<td>17</td>
</tr>
<tr>
<td>Jan.2015</td>
<td>542</td>
<td>39</td>
<td>14</td>
</tr>
<tr>
<td>Feb. 2015</td>
<td>550</td>
<td>44</td>
<td>18</td>
</tr>
<tr>
<td>Total</td>
<td>2186</td>
<td>161</td>
<td>64</td>
</tr>
</tbody>
</table>

Table 6:

<table>
<thead>
<tr>
<th>Month</th>
<th>Production pieces</th>
<th>Rejection Pieces</th>
<th>Blow holes defects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nov.2014</td>
<td>1016</td>
<td>58</td>
<td>26</td>
</tr>
<tr>
<td>Dec.2014</td>
<td>1018</td>
<td>61</td>
<td>28</td>
</tr>
<tr>
<td>Jan.2015</td>
<td>1008</td>
<td>59</td>
<td>25</td>
</tr>
<tr>
<td>Feb.2015</td>
<td>1006</td>
<td>56</td>
<td>24</td>
</tr>
<tr>
<td>Total</td>
<td>4048</td>
<td>234</td>
<td>103</td>
</tr>
</tbody>
</table>

Table 7:

![Fig. 6:](https://via.placeholder.com/150)

![Fig. 7:](https://via.placeholder.com/150)

![Fig. 8:](https://via.placeholder.com/150)
VII. CONTROL PHASE FOR BLOW HOLES DEFECTS
The main objective of control phase is making sure that the improved process stays in control after the solution. The control stage is last and final stage of DMAIC. After the study of Blow holes in foundry unit the following recommendations are made to control the reduction of Blow holes defects of submersible pumps parts.

1) Control the permeability of moulding Sand.
2) Control the moisture content of moulding sand.

VIII. RESULT ANALYSIS
The cost analysis of the savings in quarterly has been reflected in the following table. This table shows that product such as upper housing whose rejection cost due to defects before application of DMAIC was Rs.67230 which has been reduced to Rs. 26082 after implementation of DMAIC. The motor pulley pervious rejection cost in Rs 35720 which has been reduced to Rs.9785 and for mini chaff cutter has been reduced from 87864 to 31080 by implementation of DMAIC as shown in table 12 & 13.

IX. CONCLUSIONS
The DMAIC approach is a viable solution to their shop floor problems. This case study has substantiated the fact that many defects of sand casting can be overcome by adopting this approach. A number of experiments are carried out to validate the results which indicate that the cost of experimentation will be less, in comparison to the gain or profit of the company.

On the basis of the results, the following conclusions have been drawn:
1) DMAIC has been considered as an approach to improve quality of product and process.
2) Reduced rejection of industry.
3) The DMAIC approach provides a suitable visible road map for entire work force to achieve new knowledge.
4) Accuracy of this approach is very high.

X. SCOPE FOR FUTURE WORK
1) The work can be implemented on other foundry.
2) The work can be apply with Lean manufacturing and supply chain management technique to achieving good quality.
3) The data can be compared and integrated with JIT and Kaizen to improve quality.
4) Integrate the DMAIC approach with Taguchi’s method to optimize the quality.

REFERENCES


