Application of DMAIC for Process Industry: A Case Study

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Abstract

The present work deals with application of DMAIC for minimization of sand casting defects in a process industry. DMAIC approach is justified when root cause of defect is not traceable. At present, global and competitive environment, foundary 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 faundary, 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.

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.

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] thatDMAIC 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.[1]

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 product 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.

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. 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.

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.

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.

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.

Cause for blow holes

Excess moisture in molds or cores.

High moisture content of mould.

Inadequate venting in the mould.

Insufficient evacuation of air and gas from the mold cavity.

Insufficient mold and core permeability.

Low permeability of moulding sand.

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 too 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

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.

Two main test were conducted

1 Moisture content test
2 Permeabilitytest

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

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.

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.

$$\text{Permeability number} = \frac{VH}{PAT}$$

V= volume of air in cc
H= height of sample in cm
P = Pressure of air in gm. $/cm^2$
A = Cross sectional area of sample in cm^2
T = time in minutes and recorded was 122 cc/min.

So it is clear from above discussion and compare with Specification of the parameters for molding (From BS 6615:1996) the quality of sand was not good because moisture in sand was high and permeability was less. Therefore to reduce the rejections it was necessary that sand characteristic should be as per specifications to achieve efficient results.

IMPROVEPHASE FOR BLOW HOLES DEFECTS:

These are the following improvement which is given below.

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.

After implementation of these improvements, the data of the company was collected again. The table 6 show the data collection of upper housing after improvement. Same as table 7 and 8 shows the collection data after improvement of motor pulley and mini chaff cutter respectively.

CONTROL PHASE FOR BLOW HOLES DEFECTS

The main objective of control phase is makingtoo 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 holesin 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.

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 DMAICwas Rs.67230 which has been reduce 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.

For experimental measurement we have added a quantity of 6.5 kg of fresh new sand in sample of 100kg of reused sand to control moisture content and its permeability. The additional material added cost has been shown in table 14.

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 forentire work force to achieve new knowledge.
4. Accuracy of this approach is very high.

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.

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Month	Production Pieces of upper housing	Rejection Pieces	Blow holes defects
May.2014	540	108	47
June.2014	515	102	42
July.2014	525	106	45

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Table No.1

Table No.2

Month	Production Pieces of motor pulley	Rejection Pieces	Blow holes defects
May.2014	1042	187	84
June.2014	1036	184	79
July.2014	1054	182	78
Aug.2014	1008	178	75
Total	4140	731	316

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Aug.2014	512	99	43
Total	2092	415	177

Table No. 3

Table No. 4

Month	**Production** **Pieces of hand wheel**	**Rejection** **Pieces**	**Blow holes defects**
May.2014	5034	837	256
June.2014	5042	846	264
July.2014	5040	833	259
May.2014	5045	847	267
Total	20161	3363	1046

Table No.5

S.N	**Addition of new** **silica sand**	**Moisture**	**Permeability**
1	5 %	5.74 %	138 cc / min
2	5.5 %	5.06 %	159 cc / min
3	6 %	4.68 %	176 cc / min
4	6.5 %	3.82 %	188 cc/ min

Month	**Production** **pieces**	**Rejection** **Pieces**	**Blow holes defects**
Nov.2014	546	37	15
Dec.2014	548	41	17
Jan.2015	542	39	14
Feb. 2015	550	44	18
Total	2186	161	64

Defects	No. of defective pieces	Percentage of rejection
Blow holes	1539	5.83%

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Table No. 6

Defects	No. of defective pieces	Percentage of rejection

Table No. 7

Month	Production pieces	Rejection Pieces	Blow holes defects
Nov.2014	1016	58	26
Dec.2014	1018	61	28
Jan.2015	1008	59	25
Feb.2015	1006	56	24
Total	4048	234	103

Table No.8

Month	Production pieces	Rejection Pieces	Blow holes defects
Nov.2014	5021	305	94
Dec.2014	5016	302	92
Jan.2015	5014	299	89
Feb.2015	5018	307	95
Total	20069	1213	370

Table No. 9

Table No. 10

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Blow holes	537	2.04%

Defects	Before improvement	After improvement
Blow holes	5.83%	2.04%

Table No. 11

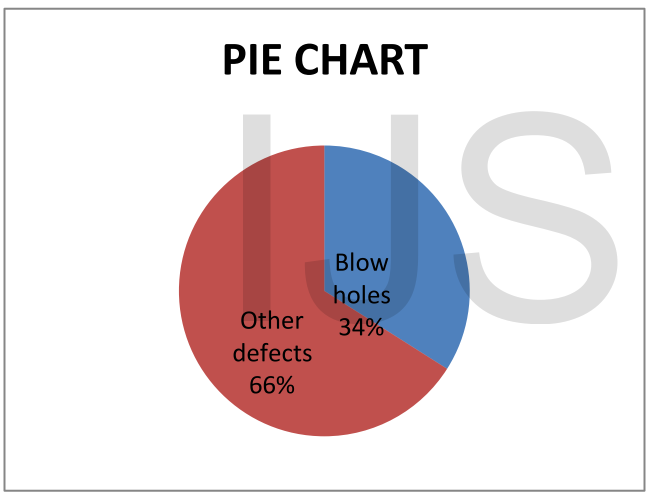
Month	Type of defects	Number of defect	Percentage of defect	Factor	Result	Suggestions
Nov.2014-Feb(2015)	Blow holes	537	2.04 %	Moisture (3.5-4.6) % Permeability (140-220)cc/min	High satisfaction	Control moisture and permeability

Table No.12

S.No.	Product	Cost (Cast iron)@ 56/kg Wt	cost	Previous rejection cost in Rs	After implementation of modification (rejection cost in Rs)
1	Upper housing	2.9 kg	162	177 x 162 = 28674	64 x 162=10368
2	Motor pulley	1.7 kg	95	376 x 95 = 35720	103 x 95= 9785
3	Mini Chaff cutter wheel / Hand wheel	1.5Kg	84	1046 x 84= 87864	370 x 84= 31080
		Total cost		152256	51233

Fig. No. 1

Fig. No. 2



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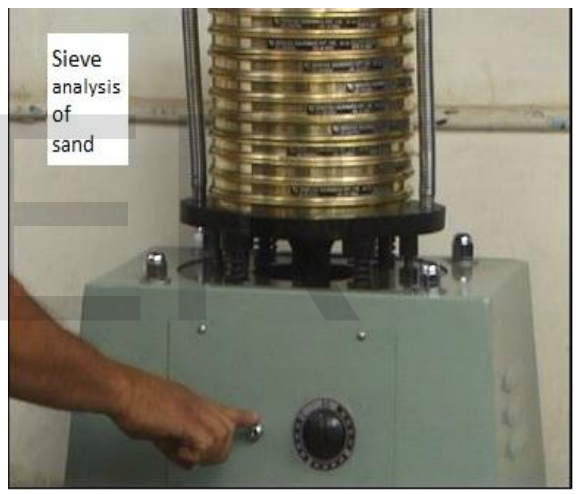

Fig.No. 4

Fig.No. 5

Fig.No. 6

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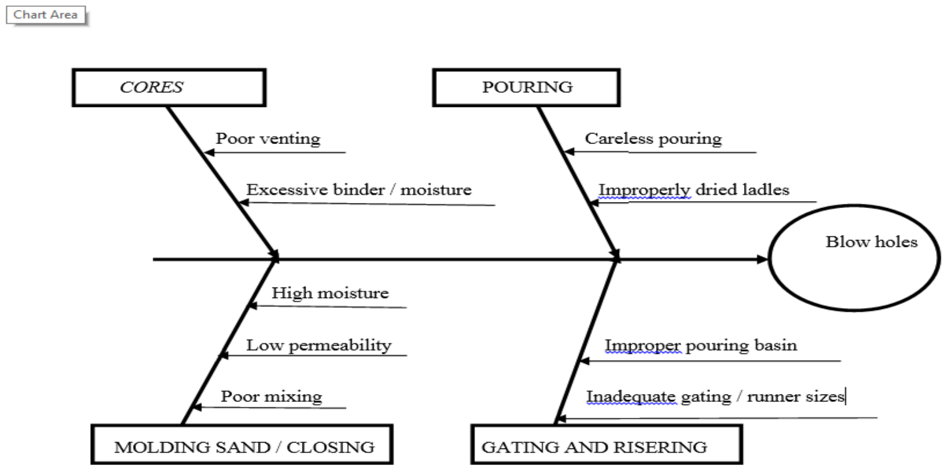

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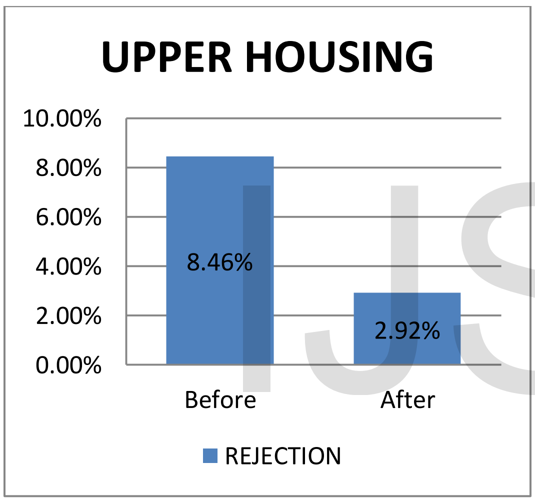

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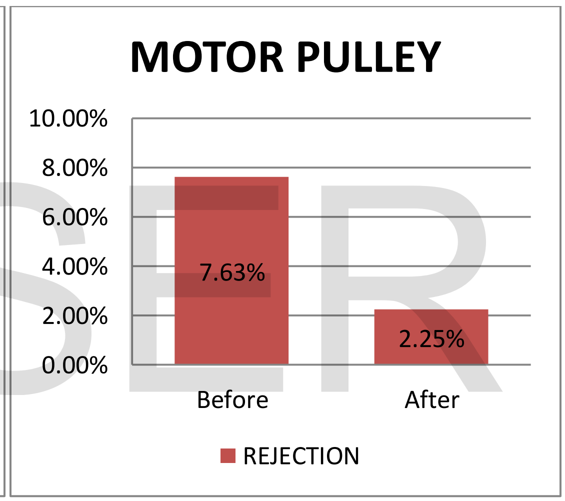

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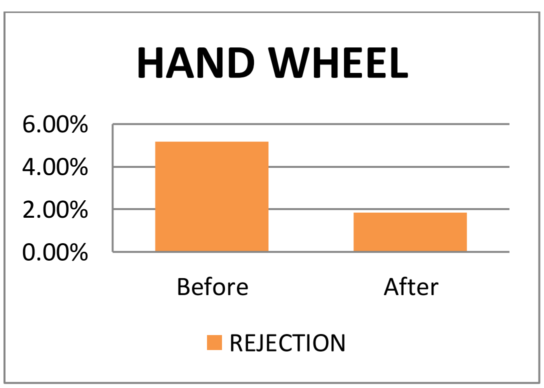

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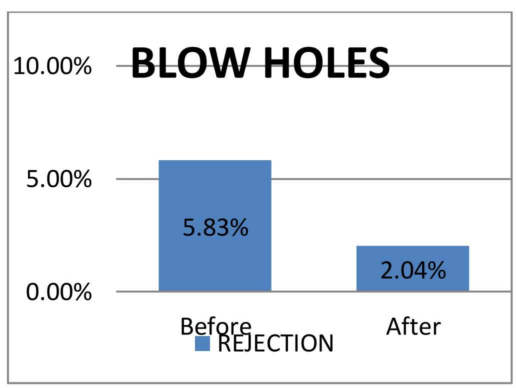

Fig. No. 1