Utilization of six sigma(DMAIC) Approach for Reducing Casting Defects

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Abstract— DMAIC approach is a business strategy used to improve business profitability and efficiency of all operation to meet customer needs and expectations. In the present research work, an attempt has been made to apply DMAIC (Define, Measure, analysis, improve, control) approach. The emphasis was laid down towards reduction in the defects (Blow holes, Misrun, Slag inclusion, Rough surface) occurred in the sand castings by controlling the parameters with DMAIC technique. The results achieved shows that the rejection due to sand casting defects has been reduced from 6.98% to 3.10 % which saved the cost of Rs.2.35 lac appx.

Keywords—Six Sigma; DMAIC, Chaff Machine, Casting Industry, Measure Phase, Pie Chart, Ishikawa, Improve Phase, Cost Benefit.

1.INTRODUCTION

In today highly competitive scenario the markets are becoming global and economic conditions are changing fast. Customers are more quality conscious and demand for high quality product at competitive prices with product variety and reduced lead time. DMAIC is a data-driven quality strategy used to improve processes. It is an integral part of a Six Sigma initiative, but in general can be implemented as a standalone quality improvement procedure or as part of other process improvement initiatives such as lean.

The DMAIC technique is an overall strategy to accelerate improvements in its processes, products and services. This approach is a project driven management approach to improve the Organization products, services and processes by continually reducing defects in the Organization. It is a powerful improvement business strategy that enables companies to use Simple and statistical methods for achieving and sustaining operational excellence. When Improving a current process, if the problem is complex or the risks are high, DMAIC should be The go-to method. Its discipline discourages a team from skipping crucial steps and increases the chances of a successful project, making DMAIC a process most projects should follow.

1. If the risks are low and there is an obvious solution, some of the DMAIC steps could be skipped, but only if:
2. Trustworthy data show this is the best solution for your problem.
3. Possible unintended outcomes have been identified and mitigation plans have been developed.
4. There is buy-in from the process owner.

DMAIC approach differs from other quality programs in its top down drive in its rigorous methodology that demands detailed analysis fact based decisions. It is a rigorous data driven method for dealing with defects, waste and quality problems, in manufacturing, services and other business activities. This approach is an upcoming quality improvement process and is proving to be a powerful tool for solving complex problems. It would not work well without full commitment from upper management .It is a scientific method to improve any aspect of a business, organization process. DMAIC is a methodology to

1. Identify improvement opportunities.
2. Define and solve problems
3. Establish measures to sustain the improvement.

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 of exceed customer's needs and expectation. DMAIC is a customer-focused program where cross functional teams works on project aimed at improving customer satisfaction.

1.2 KEY PLAYERS OF DMAIC METHODOLOGY

Key players are the persons in the industry who play an important role in the in the industry. Their duties and assignments discussed as below.

Champion: He is the business leader responsible for overall deployment. Champion ensures that process owner support is there during all phases. Champion learn DMAIC philosophies, deployment strategies, which include selecting high impact projects, choosing and managing the right people to become master belt. Champion helps transferring project ownership from black belt to manager who owns the process upon completion of corrective actions.

Black Belt: The Quality leader acts as a team leader in DMAIC project. He is responsible for training and deployment. He is all day problem solver and assist black belt in applying the method correctly in unusual situations. In organization, normally manager acts as a black belt.

Green Belt: These employees in the organization execute DMAIC as a part of their overall job while working with black belt. They gain experience in the practical application of DMAIC methodology and tools. They work as team member in black belt project. Normally shift supervisor's acts as green belt.

1.3 THE FIVE STEPS TO DMAIC APPROACH

The DMAIC methodology has a core process: Define-Measure-Analyze-Improve-Control (DMAIC) methodology. The five steps to DMAIC approach are shown in Fig. 1.1.

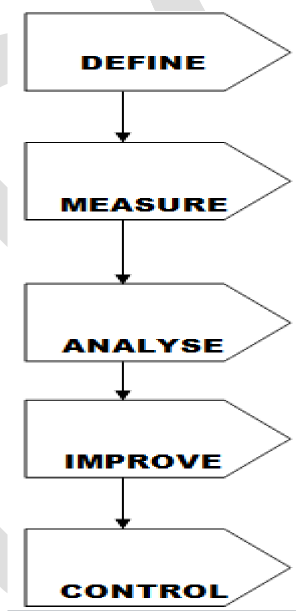

Fig. 1.1 - Five Steps to DMAIC approach

1. Define: The definition of the problem is the first and the most important step of any DMAIC project because a good understanding of the problem makes the job much easier. An average definition may mislead people into trying to achieve goal which are not required or making the problem more complex .Thus, we can say that the definition of the problem forms the backbone of any DMAIC project.

2. Measure: This problem is affecting all of the departments of the business in the form ofcustomer service, because of its inability to answer questions from the customers on differentproducts or other issues. Many of the customers may stop returning if customer servicecontinues to suffer, and this will definitely affect the financial position of the business.From the information collected during the conversation, the extent of the problem for thephone operators is excessive workload and presumed higher stress level due to this.

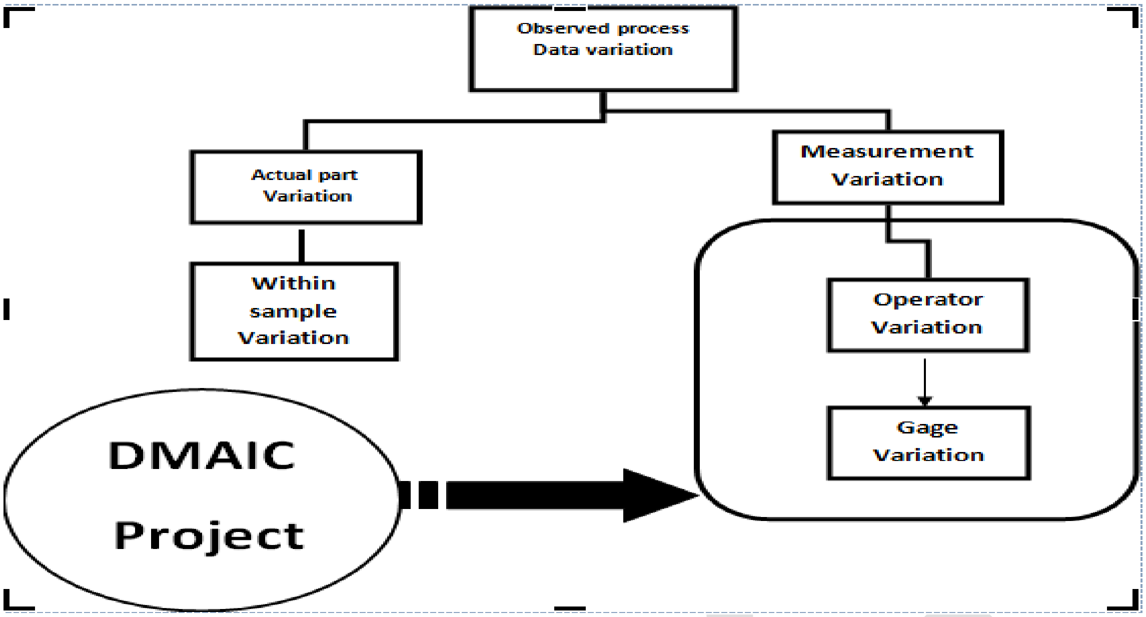

Fig. 1.2 – Measurement Variation of System

3. Analyse: The analyse phase examines the data collected in order to generate a prioritized list of source of variation. It is the key component of any defect reducing program. This is the stage at which new goals are set and route maps created for closing the gap between current and target performance level. The conventional quality technique like brainstorming, root cause analysis, Cause and effect diagram etc. may be used for carrying out the analysis.

4. Improve: Improve the process to remove cause of defects. Specific problem identified during analysis

1. Use of brain storming and action workouts
2. Extracting the vital few factors through screening
3. Understanding the correlation of the vital few factor
4. Process optimization and confirmation experiment.

5 Control: Control the process to make sure that defects do not recur i.e. remove the root cause of the problem. The control phase is preventive in nature. All the specific identified problems from the analysis phase were tackled in the control phase. It defines control plans specifying process monitoring and corrective action. This phase provides systematic re-allocation of resources to ensure the process continues in a new path of optimization. It also ensures that new process conditions are documented and monitored.

2.PROBLEM FORMULATION

In all processes the smallest variation in quality of raw material, production conditions, operator behavior 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 crucial 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.

Present study was done at SHREE BALAJI CASTING SAMALKHA, PANIPAT on application of DMAIC methodology and Selection of tools and techniques for problem solving, because of its high rejection rate. The main component of SHREE BALAJI CASTING SAMALKHA, PANIPAT was Upper gear, Lower gear, Key, Roller sporting arm, Worm gear.

2.1 OBJECTIVES OF THE STUDY

The objectives for DMAIC approach implementation at SHREE BALAJI CASTING SAMALKHA, PANIPAT are as follows:--

1. *To identify the root factors causing casting defects*
2. *To improve the quality by reducing the casting defects*

The present work deals with elimination of casting defects in a foundry industry. DMAIC approach is justified when root cause of defect is not traceable. In the present work, an attempt has made to reduce the defects in castings in a foundry shop with the application DMAIC approach. In the case study the sand casting process has divided in the three stages

(A) First stage includes-

- Sand preparation
- Mould making
- Core making

(B) Second stage includes-
Melting and pouring of metal and maintaining accurate chemical composition
(C) Third stage includes-
Fettling, cleaning and machining operation of casting
Step vise application of the DMAIC technique as discussed as below

3. DEFINE PHASE

The present case study deals with reduction of rejection due to casting defects in a foundry industry. The company is making cast iron castings of handcraft components such as Upper gear, Lower gear, Worm gear, Key, Roller sporting arm in large scale and having rejection in the form of Blow hole, Misrun, Rough surface and slag inclusions .The five important part of industry were chosen for complete analysis.

3.1 UPPER GEAR

The upper gear of chaff machine connects through the rolling shaft and rotates by lower gear. It show the rejection due to casting defects in a foundry industry. Having rejection in the form of Blow hole, Misrun, Rough surface and slag inclusions .The five important part of industry were chosen for analysis.

3.2 LOWER GEAR

The lower gears of chaff machine connect through the rolling shaft and rotate to worm gear. It show the rejection due to casting defects in a foundry industry. Having rejection in the form of Blow hole, Misrun, Rough surface and slag inclusions .The five important part of industry were chosen for analysis.

3.3 WORM GEAR

The worm gears of chaff machine connect through the fly wheel shaft .it show the rejection due to casting defects in a foundry industry. Having rejection in the form of Blow hole, Misrun, Rough surface and slag inclusions .The five important part of industry were chosen for analysis.

3.4 ROLLER GEAR SPOTING ARM

The Roller gear sporting arm of chaff machine the arm provide sport of rolling gear.it Show the rejection due to casting defects in a foundry industry. Having rejection in the form of Blow hole, Misrun, Rough surface and slag inclusions .The five important part of industry were chosen for analysis.

3.5 KEY

Key of chaff machine and use for nut and bolt tightness.it show the rejection due to casting defects in a foundry industry. Having rejection in the form of Blow hole, Misrun, Rough surface and slag inclusions .The five important part of industry were chosen for analysis.

The defects such as blow holes , Misrun , slag inclusion, rough surface have been identified by various method and Three months data of each part was collected from the company which shows the production and rejection status of individual part.

Table 3.1 Detection methods

S.No.	Type of defect	Detection	Appearance
1	Blow holes	Visual method	Rounded holes
2	Slag inclusion	Visual method	Pitted surface
3	Misrun	Visual method	Unfilled cavity
4	Rough Surface	Touching method	Rough surface

Table 3.2 Data collection (before improvement) - UPPER GEAR

Month	Production Piece	Rejection pieces	Blow holes defects	Misrun defects	Slag inclusion defects	Rough surface defects
Sep. 2013	4320	320	100	40	150	30
Oct.2013	4536	336	98	59	145	34
Nov.2013	4452	332	105	43	152	32
Dec.2013	3780	280	89	54	92	45
Total	17118	1286	392	196	539	141

Total production of Three months = 17118, Total rejection =1286 pieces

% of rejection = 1286/ 17118 = 0.0751 x 100 = 7.51%

Table 3.3 Data collection (before improvement) - Lower gear

Month	Production Pieces	Rejection pieces	Blow holes defects	Misrun defects	Slag inclusion defects	Rough surface defects
Sep.2013	4322	321	99	43	148	31
Oct.2013	4539	332	96	57	143	36
Nov.2013	4450	334	108	42	155	29
Dec.2013	3778	272	87	48	94	43
Total	17089	1259	390	190	540	139

Total production of Three months = 17089, Total rejection = 1259 pieces

% of rejection = 1259/ 17089 = 0.0736 x 100 = 7.36%

Table 3.4 Data collection (before improvement) – Worm gear

Month	Production Pieces	Rejection Pieces	Blow holes defects	Misrun defects	Slag inclusion defects	Rough surface defects
Sep. 2013	5020	451	219	50	141	41
Oct.2013	4998	449	214	17	169	49

Nov.2013	5110	459	225	45	139	50
Dec.2013	3940	354	186	36	121	11
Total	19068	1713	844	148	570	151

Total production of three months = 19068, Total rejection = 1731 pieces

% of rejection = 1731/ 19068 = 0.0907 x 100 = 9.07 %

Table 3.5 Data collection (before improvement) – Roller sporting arm

Month	**Production Pieces**	**Rejection pieces**	**Blow holes defects**	**Misrun defects**	**Slag inclusion defects**	**Rough surface defects**
Sep. 2013	3541	141	79	19	29	14
Oct.2013	3499	139	76	22	27	14
Nov.2013	3522	140	68	27	39	11
Dec.2013	2981	119	59	18	24	18
Total	13543	539	282	86	119	57

Total production of three months = 13543, Total rejection = 539 pieces

% of rejection = 539/ 13543 = 0.039 x 100 = 3.9%

Table 3.6 Data collection (before improvement) – Key

Month	**Production Pieces**	**Rejection pieces**	**Blow holes defects**	**Misrun defects**	**Slag inclusion defects**	**Rough surface defects**
Sep. 2013	3219	192	68	38	62	24
Oct.2013	3192	191	72	35	59	25
Nov.2013	3304	198	74	37	63	24
Dec.2013	2813	168	58	39	49	22
Total	12528	749	272	149	233	95

Total production of Three months = 12528, Total rejection = 749 pieces

% of rejection = 749/ 12528 = 0.0597 x 100 = 5.97%

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

Total production of 5 parts in Three months = 79346

Total rejection pieces = 5546

Overall % age of rejection 5546/ 79346 = 0.0698 x 100 = 6.98%

Table 3.7 Total rejection data

Defects	No. of defective pieces	Percentage of rejection
Blow holes	2180	2180/79346= 0.0274 x 100 = 2.74%
Misrun	769	769/79346= 0.00969 x 100=0.96%
Slag inclusion	2001	2001/79346= 0.0252 x 100=2.52%
Rough surface	583	583/79346=0.00734x 100=0.73%

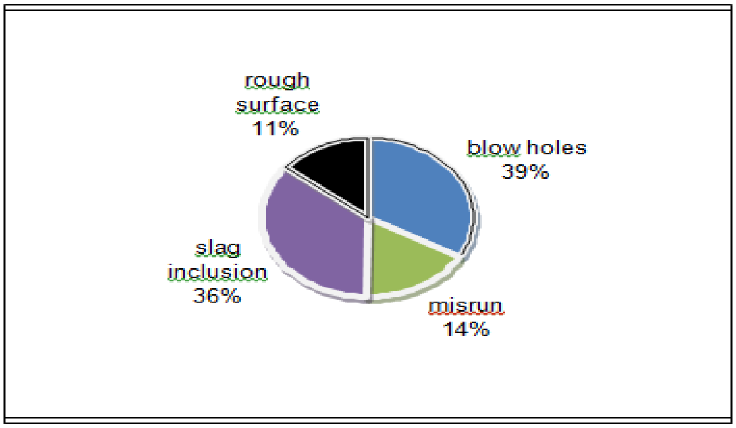

Fig. 3.1 Pie Chart

After collecting the complete data it was clear that rejection was high due to blow holes and slag inclusion casting defects. Therefore more stress has been given on these defects to reduce the rejection in the industry.

4. 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. One of these is the "5M" diagram, so called because five of the categories on the branches begin with the letter M ("Personnel" is also referred to as "Man").

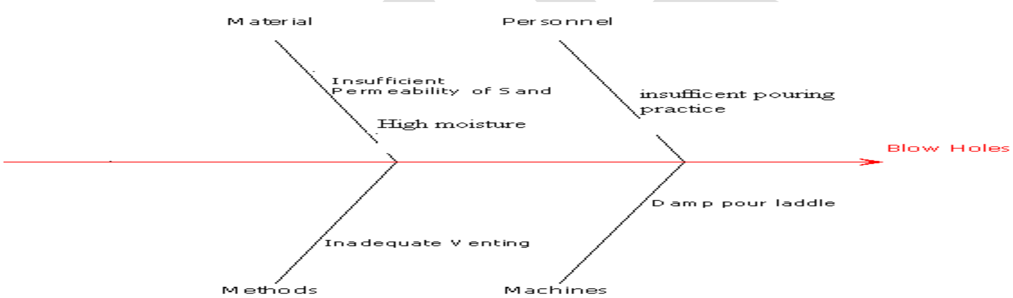

FIG.4.1 ISHIKIWA DIAGRAM FOR BLOW HOLES DEFECTS

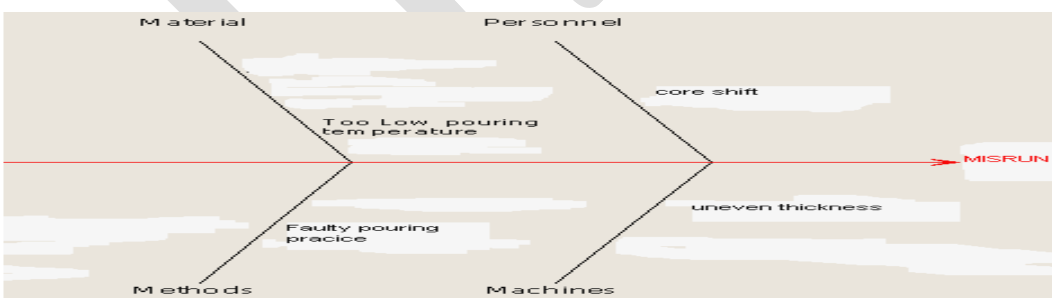

FIG 4.2 ISHIKIWA DIAGRAM FOR MISRUN DEFECTS

5. IMPROVE PHASE

5.1 Improvement in blow holes defects: The root factors for blow holes defects were high moisture and low permeability. The industry was using 5% of new silica sand and 95% 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 improve the blow holes defects it was necessary to increase the percentage of new silica sand to reduce the moisture and increased the permeability. The different results have been obtained by increasing the new silica sand as below.

Table 5.1 Percentage recorded of moisture and permeability

S.N	Addition of new silica sand	Moisture	Permeability
1	5 %	6.01 %	125 cc / min
2	5.5 %	5.45 %	131 cc / min
3	6 %	4.92 %	138 cc / min
4	6.5 %	4.32 %	145 cc/ min

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. After testing the sand the following results were obtained which were in comparison with the standard results towards achievements of reduction of casting defects.

5.2 Improvement in Rough surface defects: The root factors for rough surface defects were poor coating of pattern, loose ramming so to remove this defects it was very necessary to correct the coating of patterns and loose ramming. Therefore some improvements have been done to reduce the rough surface defects.

1. Soft ramming has been improved by addition of coal dust from 0.9% to 1.1%.
2. Varnish coating on the pattern has been used.
3. Coating of mould inner surface by zirconium paste.

5.3 Improvement in Misrun defects: The root factors for Misrun defects were core shift and low pouring temp .Therefore to remove this casting defect temp. has been improved and core shift has been controlled. So following action has been taken to improve this defect.

1. Misrun defects have been minimized by increasing tapping temp. 1195 degree to 1235 degree centigrade with addition of flux (lime stone) from 0.2% to 0.3%.
2. To avoid core shift chaplets have used to reduce Misrun defects

5.4 Improvement in slag defects: The root factors for slag defects were rough ladle lining and skimming metal. Therefore to reduce the slag inclusion defect some new material has been added which was not used by the company before applying technique.

1. Slag defects have minimized by addition of slax-30 (Foseco foundry data hand book pp. 229) material up to 2%
2. By using clean ladle

After implementation of these improvements, the data of the company was collected again.

Table 5.2 Data collection (after improvement) – upper gear

Month	Production Pieces	Rejection pieces	Blow holes defects	Misrun defects	Slag inclusion defects	Rough surface defects
Feb 2014	4439	147	42	27	57	21
March 2014	4612	158	48	37	49	24
April 2014	4507	167	51	39	47	30
May2014	4527	135	42	28	40	25
Total	18085	607	183	131	193	100

Total production of Three months = 18085, Total rejection =607 pieces

% of rejection =607 / 18085 = 0.0335 x 100 = 3.35%

Table 5.3 Data collection (after improvement) – Lower gear

Month	Production Pieces	Rejection pieces	Blow holes defects	Misrun defects	Slag inclusion defects	Rough surface defects
Feb 2014	4421	138	40	38	38	22
March 2014	4827	144	48	41	35	25
April 2014	4547	141	45	38	37	21
May2014	4617	151	41	52	32	26
Total	18412	574	169	169	142	94

Total production of Three months = 18412, Total rejection =574 pieces

% of rejection =574/ 18412 = 0.0311 x 100 = 3.11

Table 5.4 Data collection (after improvement) – Worm gear

Month	Production Pieces	Rejection Pieces	Blow holes defects	Misrun defects	Slag inclusion defects	Rough surface defects
Feb 2014	5535	227	86	57	62	22
March 2014	5451	231	92	49	65	25
April 2014	5315	213	80	38	68	27
May2014	5467	230	87	48	70	25
Total	21768	901	345	192	265	99

Total production of Three months = 21768, Total rejection =901 pieces

% of rejection = 901/ 21768= 0.0413 x 100 =4.13%

Table 5.5 Data collection (after improvement) – Roller sporting arm

Month	Production Pieces	Rejection pieces	Blow holes defects	Misrun defects	Slag inclusion defects	Rough surface defects
Feb 2014	3637	65	28	12	17	08
March 2014	3840	61	27	13	15	06
April 2014	4056	70	25	13	22	10
May2014	3767	57	20	15	15	07
Total	15300	253	100	53	69	31

Total production of Three months = 15300, Total rejection = 253 pieces

% of rejection =253/ 15300= 0.0165 x 100= 1.65%

Table 5.6 Data collection (after improvement) – Key

Month	Production Pieces	Rejection pieces	Blow holes defects	Misrun defects	Slag inclusion defects	Rough surface defects

Feb 2014	3513	98	46	10	32	10
March 2014	3367	95	42	13	28	12
April 2014	3573	97	42	15	25	15
May2014	3586	99	43	17	26	13
Total	14039	384	173	55	111	50

Total production of Three months = 14039, Total rejection =384 pieces % of rejection =384/ 14039= 0.0273x 100= 2.73%

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

Total production of 5 parts in Three months = 87604

Total rejection = 2719

Overall %age of rejection = 2719 / 87604 = 0.0310 x 100= 3.10%

So after the complete analysis it was found that rejection due to casting defects has been reduced.

Table 5.7 Improvements in rejection

Defects	**Before improvement**	**After improvement**
Blow holes	2.74%	0.11%
Misrun	0.96%	0.68%
Slag inclusion	2.52%	0.89%
Rough surface	0.73%	0.42%

So after the complete analysis it was found that rejection due to casting defects has been reduced. The DMAIC approach has been successfully applied and rejections due to casting defects have been reduced from 6.98% to 3.10%.

6. RESULTS AND DISCUSSION

From the result of the application of DMAIC approach in the foundry shop the following results were obtained. The rejection due to Blow holes defects were reduced from 2.74% to 0.11% by reducing the moisture and increasing the permeability of sand. The rejection due to slag defects were reduced from 2.52% to 0.89% by using slag -30 material. The rejection due to Misrun defects was reduced from 0.96 % to 0.68% by using chaplets. The rejections due to rough surface defects were reduced from 0.73 % to 0.42% by addition of coal dust. The overall result of present work is clearly shows that by applying DMAIC approach the rejection has reduced from 6.98% to 3.10% and saving of cost Rs 2.35 lac app.

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