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Application of Six Sigma in Manufacturing of Draft Gear

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Abstract : As for production in the world, the foundry industry is still the "Base'' for all kind of automotive industry world-wide. A company to remain successful there is an ongoing need to add value and be a supplier of choice, seeking customer expectation of good quality product, within specified period and with a profit margin. To respond the customer requirements various engineering and management tools have been developed like, JIT manufacturing, Enterprise resource Planning, ISO 9000, TQM, and lean manufacturing. A new concept of Six Sigma with its quality control tools have been adopted world-wide in manufacturing sector as well as service sector to improve product quality and reduce variations to make production process robust. The moto of this study is to apply six sigma approaches through its DMAIC (Define-Measure-Analyze-Improve-Control) (Smętkowska & Mrugalska, 2018) methodology on manufacturing of "draft gear'' a major component of railway wagon freight cars. For measurement system analysis, 'Minitab19' software is used to draw the Pareto chart to prioritize the defects, used for cause-and-effect diagram & also to draw the control chart for attributes. The objective of this work includes literature review for detection of casting defects & their remedies in casting component using Six Sigma approach through its DMAIC methodology. (Malek & Desai, 2015)The approach is to investigate the sources of defect & to reduce these casting defects which have appeared in this particular component and improve the level of Six Sigma for the product in the organization with the help of calculating defect per million opportunities and process yield.(Coskun et al., 2016)

***IndexTerms* - Six Sigma, Draft gear, wagon, DMAIC, Pareto**

I. Introduction

In modern era a strong quality management tool named as Six Sigma which is more required to make strong business strategy. Six Sigma is also a business management tool which direct towards improving the quality of product processes by minimizing and eventually removing the errors and variations. The concept of Six Sigma was introduced by Motorola(Raisinghani et al., 2005) in 1986, but was popularized by Jack Welch who implemented this tool in his business processes at General Electric. The concept of Six Sigma came into picture when one of Motorola's senior executives complained of Motorola's bad quality. Bill Smith eventually formulated the methodology in 1986. **Tomkins**(*IMPROVING PRODUCTIVITY USING LEAN SIX-SIGMA*, n.d.) **(1997) defines Six Sigma to be "a program aimed at the near-elimination of defects from every product, process and transaction.** Six Sigma process has two main dimensions: DMAIC (D-Define, M-Measure, A-Analyze, I-Improve, C- Control).), which is applicable to an existing product or process to be improved, and DMADV (D-Define, M- Measure, A-Analyze, D-Design, V-Verify) which is applicable to new products or processes, to be designed and / or implemented in a manner that will provide a Six Sigma performance. The study is focused on the applicability of Six Sigma (DMAIC approach) (Kumaravadivel & Natarajan, 2013)on the manufacturing of draft gear housing and deals the quality issue of component, it can be understood using its methodology and six sigma levels with DPMO (Coskun et al., 2016)(defective parts per million opportunity) and process yield.

The draw gear is also known as the "draft gear'' (Singh, 1961) is the assembly behind the coupling in the each end of the wagon take care of the tension and compression forces in the trains. The coupling action in the trains is automatic the draw bar is cast together with the coupler head the tail end of the draw bar is connected with the draft gear through a central pin. Different types of draft gear used in trains. Mostly two types of Draft gear is used by Indian Railway RF361 and MK 50 these are the high capacity draft gears. The pull action-commonly called draft-is necessary for transmitting the drawbar pull exerted by the locomotive on the train.(Lei et al., 2019). RF361 draft gear is fully enclosed contained unit assemble with the recompression force of the rubber pads so that all parts are in tight relation with one other. The draft gear is fitted in the yoke following plate. The different component of the same draft gear are **1)** Housing (Cylinder) **2)** Wegde **3)** Shoes {3 nos} **4)** Top follower 5) Rubber pads in many units(Each are having natural rubber capacity to absorb absorbing high level of longitudinal forces) which are rinsing due to operation like accelerating and braking and also due to changes in tracks. In the case of freight trains the pull action exerted by the same will pass through the draft gear of the wagons which are quickly following the power unit and it is therefore necessary that such a draft gear should have enough strength to withstand the maximum stress.

Table 1: Six Sigma Application

Problem Occurrence	Find the issues that slows the business performance	Define stage	D
Statistical Occurrence	Find the issue using evidence & data	Measure stage	M
Statistical Occurrence	Discover steadfast data drive	Analyze stage	A
Practical Occurrence	Find out a solution to increase price by waste reduction	Improve stage	I
Control Plan	Design or Draw a system to maintain long term relation	Control stage	C
Control Plan	Calculate & earn the benefits of financial achievements		6 σ

Every day in railway locomotives the rear part is subjected to fully damaging forces. The draft gear JOB is to cushion these forces by pushing, pulling, coupling, starting and stoping action of the rear carts. The draft gear is located in the rear part of the locomotive by front and rear draft lugs behind the follower and coupler. During an impact couple event the couple movers forward by pushing the follower block and compressing the draft gear towards is known as the BUFF event. The centre slit pocket has rear draft lugs that holds the draft gear stationary. The draft gear absorb impact energy of this buff coupling event to minimises the forces transmitted into the cart body and bleeding. During the draft event the coupler extends from the cart by pulling the yoke against the rear of the draft gear housing housing by compressing the clutch against the follower block which is held stationary against the front lugs. This work manages energy during trains startup and control run-in and run-out train action event to protect or minimising wear. While rear carts are travelling down the tracks the draft gear compress an extent to manage energy from changes in speed in demography. The draft gear absorb energy during both buff and draft event to reduce In-train forces during coupling. The objectives of proposed work on draft gear housing, a major safety component of railway wagon manufactured by FRONTIEER ALLOY STEELS LIMITED RANIA KANPUR study relates the foundry operations of draft gear housing and the root causes of defects arises in component which becomes the reason of rejections of component. Six Sigma methodologies based on DMAIC approach employed to detect root cause of defect in component and remove the defect up to certain extent and emphasise the sigma level of company.

II. Literature Review

Quality is an important discriminating factor for many centuries now as the manufacturing industry was the first to take a hard, scientific look at quality. Manufacturing organization focused with product quality as well as processes. Manufacturing agency uses standard and consistent process improvement methodologies to improve both manufacturing processes and production quality. According to **'GENICHI TAGUCHI'** (Ganganallimath et al., 2019)Cost is more important than Quality but Quality is the best way to control the Cost. They measure quality prior in terms of measurements and now a day's measurement is done using statistical methods. Seeking customer expectation, Six Sigma understands the elements of waste. Six sigma (DMAIC methodology) skills are used to achieve sustainable quality improvement through process improvement. (Chen & Brahma, 2014)Most of the casting defects arise due to the uncontrolled process parameter; hence concern is to produce the defects free parts (zero defects). To control the event essentials, it is necessary to have knowledge about effect of event essentials on casting product and their influence on defect. For defect minimization through process improvement using six sigma tools, as discussed further.

Virender Verma, Amit Sharma & Deepak juneja has used The DMAIC (Journal & Volume, 2014)(define-measure-analyze-improve-control) approach in SHREE BALAJI CASTING SAMALKHA, PANIPAT By using this approach they solved a predefined problem of casting defects. Thus that could able to reduce high defect rate associated with it. The defects as Misrun, blow holes, slag inclusion, rough surface have been observed by using various method and Three months data of each part was collected from the organization which shows the production and rejection status of individual part.

Even more recently applied the six sigma approach that aims to improve the performance of process of production in automotive industry using statistical technique of Six Sigma. Analysis was done on single pin insertion process (aimed to calculate force during pin insertion) on PCB which entailed high rejection cost and line stop that affect the final assembly process. Using DMAIC method the problem was measured and analyzed starting from the machine and with two products which causes increse of rejection. An exhaustive study was done and six sigma methodologies concluded that failure was occurred due to high force during pin insertion which was occurred by the interaction of three possible reasons. The set of improvement was implemented and force during pin insertion reduced to figures near to nominal. The effectiveness evaluation of the improvements action results in the no defective units from 3200 PPM to 310 PPM with increase in the sigma level from 4.22 to 4.94, results in significant savings of the company around thousand of Euros.

Preliminarily, explained that Six Sigma methodology was implemented only in the productive sector, but once the benefit of its application in terms of performance improvement and cost reduction was found, it quickly expanded to different functional areas such as administrative, marketing, engineering and purchasing. For instance illustration Six-Sigma (DMAIC) methodologies used to enhance quality by reducing defects using scientific process improvement process. In this project, we deal with high rejection rate of cylinder block casting(Dangi & Malik, n.d.). The overall foundry rejection of Simpson 3Ø cylinder block was very high. It is on the top priority in plant Cylinder blocks family as expressed in severity table. The average foundry rejection of this product is 84,000

PPM against the target of 55,000 PPM due to which the plant was facing a loss of around INR 20 laces/Annum**.** The possible causes arrived from deliberate process were fitted on each category of cause and effect diagram. Overall Rejection trend shows reduction of rejection after quick win enhancement and after reduction of blow hole defect.

Results of investigation validate that Six Sigma DMAIC approach significantly aimed at reducing rejections(Malek & Desai, 2015) or improving sigma level through small improvements in the manufacturing system process. Results of investigation validated that Six Sigma DMAIC approach significantly aimed at reducing rejections or improving sigma level through small improvements in the manufacturing system process. According to in global competition market, customer demands world quality product, range of variety of product with reduced lead time had a major influence on foundry industries. To respond these needs various industrial engineering and management approaches had emerged like statistical quality control, ISO 9000, Quality circles, process capability study and failure mode effect analysis etc. The DMAIC(Pranavi et al., 2019) methodology of six sigma with its tools achieved benefits in terms of quality which in turn in cost and improvement in six sigma level with critical success factors

III. METHODOLOGY

Draft Gear Housing are produced by the Green sand casting process. Following is the comprehensive manufacturing process of draft gear housing:

- **Methoding***:* Casting solidification software is applied to quantify castings for potential defects and to make sure the casting for production. Calibrated running, gating and risering system together with application of chills and chaplets shall be evolved with help of casting solidification software. Casting solidity must be proved with the support of casting solidification software to acquire proper inner solidity excellence. These excellence are calculated with the help of porosity percentage values.
- **Material***:*-Material of draft gear housing is selected as per the RDSO specification.Raw material, scrap & Ferro-alloys used for the manufacture of steel castings are analyzed in advance. Care is taken to ensure that the scrap selected is free from rust, grease, oil and other prohibited contaminations.
- **Process of steel making***:*- All steel melting and purification process are bring off with the aid of an Electric Arc Furnace capacity 5MT. samples are drawn at various stages of steel making including from the ladle after metal being tapped into it from arc furnace. The molten metal is tapped from arc furnace after confirming the metal chemistry through spectral analysis, to a pre heated bottom pouring ladle and from ladle to the moulds.
- **Ladle analysis***:*-Ladle inspection of steel when accomplish by spectrometer to find out the percentage of Carbon, Manganese, Phosphorus, Sulphur, Silica, Chromium, and Nickel & Molybdenum shall confirm to necessity of the RDSO specification.
- **Core making***:* -All cores are manufactured by No-Bake operation for which uninterrupted mixer with contraction table/batch mixer is accessible with the firm.
  1) **Melting***:* - An abundant carbon boil is consummate with a 20-pointcarbon reduction. Double slag operation for proper removal of Sulphur and phosphorus is looked off. Argon purging is also carried out to ensure freedom from harmful gases. Ladle pre-heatingat600or 700 degree°C is carried out. Temperature inspection in Furnace and in ladle by Immersion Pyrometer is done prior to pouring in mould.
  2) **Pouring***:*-Through pouring in mould, temperature inspection by Laser Beam type optical pyrometers is done. After pouring castings are permitted to cool to a temperature below300^{o}, at a rate that is not harmful to the castings. Moulding boxes are unlocked to extract the castings after they are cooled down adequately to room temperature.
  3) **Fettling***:*-Risers, runners and in-gates are detached from the Castings. Application of knock-off risers is preferred for enhancing the surface situation of the castings. All Castings are subsequently being properly cleaned, dressed and shot blasted to ensure freedom from surface imperfections, loosely adherent sand, scale etc.
  4) **Heat Treatment***:-*All castings are heat treated followed by fettling.. Grade-B Steel Castings are furnished normalized and tempered. State-of-the-art heat treatment furnaces are implemented and competent of carrying an even heat distribution within +/- 10^{o} throughout. Authentication is established by performing a minimum of eight zone survey on monthly basis.
  5) **Cleaning***:-*After heat treatment castings are given shot blasting to clean the surfaces, heat treatment scales and sand etc.
  6) **Gauging/machining/finishing***:-*After shot blasting, castings are inspected visually and if found satisfactory, are sent for necessary grinding/machining operations.
- **Inspection***: -*After finishing, castings are inspected for visual and dimensional checks with the help of various measuring instruments and approved gauges. Non-conforming castings are sent back to the respective shops for necessary rectification/disposal.
- **Load testing***:* -Samples are drawn from the lot and sent to the respective sheds for proof load/ destruction load testing followed by radiography and sectioning tests as and when required.
- **Painting***:* -Inspected and passed material are provided with inspection seal on each piece and thereafter given rust preventive coating as per the relevant specification.
- **Dispatch: -**Finally, inspected and passed products are dispatched to the concerned consignee.

IV. DIMAC STAGE

- Define Stage
  A SIPOC (Parkash & Kaushik, 2011)(suppliers, inputs, process, outputs, and customers) diagram is a visual technique for documenting a business process from start to finish prior to execution. SIPOC (pronounced sigh-pock) diagrams are also referred to as high level process maps due to the reason they do not contain sufficient detail. Before the process can be investigated, we shall prepare a roadmap in the form of project chart table as shown below:

Table 2: Project chart

Project title	To reduce rejection rate of draft gear housing
Project objective	To reduce present defect %
CTQs	Rejection % is large due to casting defects
Project scope	Green sand casting process
Expected benefit	Quality product & lesser defect product Consumer fulfillment Saving due to reduced defect %
Schedule	Define - one week Measure - two week Analyze – three weeks Improve – three weeks Control – three weeks

- Measure Stage

Pareto diagram This is the data collection phase and data of casted draft gear housing from April 2019 to December 2019 in greensand casting production line to investigate the problem raised by this particular item. Following table shows the total production – rejection statement of the draft gear housing.

Table 3: Production – Rejection statement for draft gear housing

Name of Month	Quantity produced	Quantity defective	Defective percentage
April 19	2600	105	4.03
May 19	2630	95	3.61
June 19	2650	107	4.03
July 19	2600	98	3.76
August 19	2620	105	4.0
September 19	2680	95	3.54
October 19	2700	115	4.25
November 19	2720	108	3.97
December 19	2750	120	4.36
Total	**23950**	**948**	**3.95**

A Pareto chart (Srinivasan et al., 2014)(**80: 20 analysis i.e. 80 % defects caused due to 20 % reasons**) is constructed regarding the casting defects. To draw the Pareto chart a table enlisting the type of defects, no of defective pieces (Cumulative sum of each month), and their cumulative percent defect is prepared below:

Table 4: Pareto analysis

Sr. No.	Type of defect for Draft Gear Housing	Quantity defective	Cumulative sum	Cumulative frequency %
1	Scab	415	415	43.77
2	Sand inclusion	325	740	78.05
3	Mismatch	68	808	85.23
4	Misrun	52	860	90.71
5	Distortion	49	909	95.88
6	Others	39	948	100
	Total	**948**		

With the help of the previous table a Pareto chart has been drawn. This chart reveals the major contributor for defect count and type of defects as shown in figure:

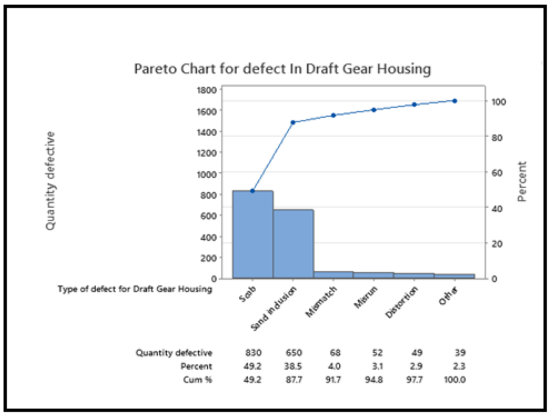

Figure 1: Pareto diagram for draft gear housing defect

The vertical axis on the left hand side of a Pareto chart indicates the overall defective count, while the right hand side represents the cumulative frequency of defect percent. The horizontal axis of a Pareto chart represents the response variable, which is the type of defect. With the help of the Pareto diagram above, this can be observed. Scab accounts for 43.77 percent of the fault, while sand inclusion accounts for 34.28 percent. According to the Pareto table, scab and sand inclusion are the primary causes of 78.05 percent of faulty castings.

Scab is the most common defect, causing the largest percentage of rejection and posing a hurdle to meeting production goals. Now, we have to apply the statistical quality control tools to calculate the current sigma level& process yield of the firm using DPMO formula & draw the control charts to understand the process capability of the firm.

DPMO- : Using table no.8, In order to calculate DPMO, there are three basic information's to be needed as given below - :

i. The number of units produced= 23950

ii. The number of defect opportunities = 06

iii. The number of defects = 948

Now,

DPMO = $\left(\frac{No.\ of\ defective\ units}{No\ of\ opportunities\ for\ defect\ X\ No.of\ units\ Produced}\right)$ X 10^6

= $\frac{948}{06\ X\ 23950}$ X 10^6 = 6597

Now we have to calculate the Process Yield of Casting Process

Yield= $\left(\frac{No\ of\ opportunities\ for\ defect\ X\ No.of\ units\ produced - No.of\ defect}{No\ of\ opportunities\ for\ defect\ X\ No.of\ units\ produced}\right)$ X 10^2

= $\frac{06\ X\ 23950 - 948}{06\ X\ 23950}$ X 10^2= 99.34 %

To calculate, sigma level of the process for above DPMO & process yield using a standard table known as process sigma table (correlation table) & can be given as

Table 5: Process sigma table

SIGMA LEVEL	DEFECT RATE (DPMO)	YIELD (%)
2	308,770	69.10000
3	66,811	93.33000
4	6,210	99.38000
5	233	99.97700
6	3.4	99.9997

On the basis of above DPMO and Process Yield, (Known as Sigma Level calculator) the Sigma Level of the process is 4.0. After precise calculation keeping each things in mind the baseline status can be tabulated as

Table 6: Base line status or Current performance of Firm for draft gear housing

Part Name	Average Defect %	Process Yield in %	DPMO	Sigma Level
Draft Gear Housing	3.95	99.34	6597	4.0

CONTROL CHART- :

Table 7: Control chart analysis for no. of defective

Sr. No.	Month	Sample Size	Defective pieces
1	April 19	1850	80
2	May 19	1850	78
3	June 19	1850	73
4	July 19	1850	79
5	August 19	1850	98
6	September 19	1850	71
7	October 19	1850	94
8	November 19	1850	76
9	December 19	1850	99
Total		16650	748

Calculation is done as

i. Center line of the process **(CL)** = np

Where=proportion defective = $\frac{Total\ No.of\ defective\ pieces}{Total\ No.of\ Production\ (Sample\ Size)}$

And n = Sample Size = 1850

Now p = $\frac{748}{16650}$ = 0.04492

Then **CL** = 0.04492 x 1850 = 83.11

i. Upper control limit of the process **(UCL)** = np + $3\sqrt{npq}$

Where q = 1 - p,

q = 1 – 0.04492 = 0.95508

Now UCL = 1850 x 0.04492 + 3 $\sqrt{1850\ X\ 0.04492\ X\ 0.95508}$

UCL = 109.84

ii. Lower control limit **(LCL)**=np - 3 $\sqrt{npq}$

LCL = 1850 x 0.04492 – 3 $\sqrt{1850\ X\ 0.04492\ X\ 0.95508}$

LCL = 56.38

On the basis of above calculation, we can draw the control chart of the current manufacturing process of Draft Gear Housing as

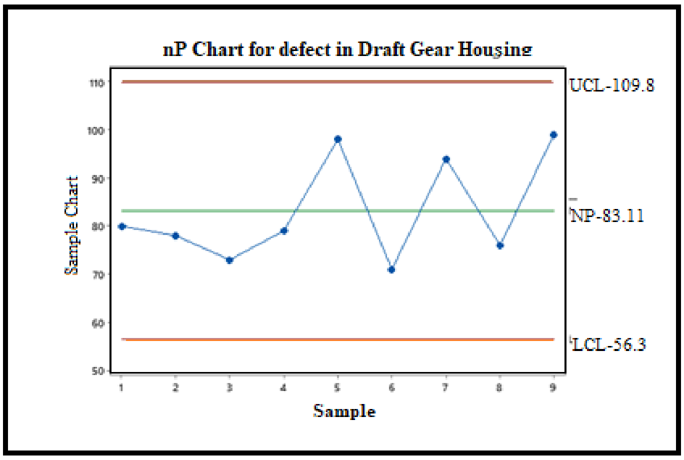

Figure 2: Control chart for production of Draft Gear Housing

It is clear from above obtained control chart, the all data points falls in between UCL & LCL, so why we can say that Process is in control.

Analyze Stage

Root cause analysis

In this segment the captured data is inspected, analyzed & prioritized in the way to investigate the possible root causes of defect i.e. scab and their effect on output. This phase examines the root cause using a quality tool i.e. root cause analysis (cause & effect diagram or Ishikawa diagram or fishbone diagram) for the defect 'Scab' which contributes the maximum towards the casting defects for the particular item. At this stage a practical problem will get converted into statistical problem, and analyzed as statistically. After planning and conducting brainstorming session by improvement team members (Including Quality assurance engineer) in casting unit. Based on the discussions upon the probable causes (including major and minor causes) as to why the scab problem occurred. The defect may be caused by five major factors, Man, Machine, Material, Method, and Environment

Defect Name: Scab

A scab is a situation where an extra layer of metal is found on the surface of the casting and can be readily reduced by scraping or peeling. Under it is found a layer of sand on the casting surface. The major reason for scabs is the sand mixture with either too much clay and or moisture quantity to allow the sand to expand appositely when the molten metal comes in connection with it. By way of correction sand properties should be inspected and corrections made in the amount of bentonite and or water being added.

In analysis Stage, while finding the root cause of defect 'scab' so many factors seem responsible primarily, but amongst those vital are few and trivial are many. Hence, the matter was discussed with the experienced foundry men and quality control engineers to establish the root causes yielding into the scabbing defect.

In order to pin point the prime cause, a systematic approach has been adopted. The standard operating range of various factors like grain size, clay content %, moisture content %, hardness & temperature that involve in sand casting as

Table 8: Operating range of factors

Sr. No.	Grain size(AFS)	Clay content %	Moisture content%	Hardness BHN	Temperature^{0}C
1	40-50	9-12	3.5-5	75-90	1610-1625

As per the standard sampling process, samples were collected at regular interval of two days, and tested in laboratory for sand grain size, moisture content, and clay content. Temperature of molten metal is also checked. Hardness of mould samples at different locations were also checked to ascertain whether ramming was proper and uniform all over.

Improve Stage

The objective of this step is to identify, test & develop the optimal solution of the problem and implement the solution to check the confirmation in form of pilot production. In analysis Stage the brainstorming session was planned and conducted to identify the root cause of defect scab. In improve Stage focus is on developing the rid of root cause of variation, test and standardize the solution. Making effective discussion with production department, quality department and supervisors in analysis Stage the probable cause of defect 'scab' is that not to meet the clay content % with standard in molding sand / system sand due to which defect appears at the in-gate of the mold.

Conducting brainstorming session with quality control department & expert foundry men the outcome had arrived that after every molding operation there is needed to perform test of clay content % in sand & try to control the value in the range of standard value i.e. 9-12 % in order to avoid the defect scab.

Table 9: In line rejection table date wise for Draft Gear Housing

FEB 2020	DEFECTIVE PIECE	MARCH 2020	DEFECTIVE PIECE
15	2	1	1
16	1	2	1
17	1	3	NIL
18	1	4	1
19	1	5	NIL
20	1	6	NIL
21	1	7	1
22	NIL	8	NIL
23	1	9	NIL
24	1	10	1
25	NIL	11	1
26	NIL	12	1
27	1	13	NIL
28	1	14	NIL
29	NIL	15	NIL

The above table shows the inline rejection due to scab per day during the period of 15 Feb 2020 to 15 March 2020, which indicates that there is an abrupt decrease in the inline rejection due to scab. The significant change is due to the use of appropriate amount of clay content % age in system sand. This table concludes that use of appropriate amount of clay content % age will give a better result which is goal of the **DMAIC** methodology.

Control Stage

Control chart

In control Stage there are some necessary action that has to be needed for production & quality department to monitor the obtained improved result& to sustain the same after implementation of the Six Sigma methodology and also to ensure the processes and products consistently meets the organization requirements. The major defects are investigated and reduced up to certain extent. The real challenge is to make the consistency of processes and products. For which, following are the necessary action in the view of control plan has been taken by the organization - :

i. Use adequate amount of clay and moisture in sand.
ii. Arrange training and counseling session of concerned people involved in molding line.
iii. Regular monitoring of sand in laboratory is required.
iv. To maintain the pouring speed of molten metal.

In addition to control Stage, the statistical quality control of any manufacturing process is necessary, for which the data is collected after enhancement Stage for the month of 15 February to 15 March 2020 & is shown in table -:

Table 10: Current Production – Rejection Statement

Name of Month2020	Quantity Produced	Quantity defective	Quantity rejected	Defective piece %
February – March	2170	22	3	1.01

Now we have to calculate the current sigma level & process yield of the firm using DPMO formula. For this

i. The quantity of units produced = 2170
ii. The quantity of defect opportunities = 06
iii. The quantity of defects = 22

Now,

$$DPMO = \left(\frac{No.\ of\ defective\ units}{No\ of\ opportunities\ for\ defect\ X\ No.of\ units\ Produced}\right)\ X\ 10^6$$

$$= \frac{22}{06\ X\ 2170}\ X\ 10^6 = 1690$$

Now we have to calculate the Process Yield of Casting Process

$$Yield = \left(\frac{No\ of\ opportunities\ for\ defect\ X\ No.of\ units\ produced - No.of\ defect}{No\ of\ opportunities\ for\ defect\ X\ No.of\ units\ produced}\right)\ X\ 10^2$$

$$= \frac{06\ X\ 2170 - 22}{06\ X\ 2170}\ X\ 10^2 = 99.83\ \%$$

On the basis of above DPMO and Process Yield, (Known as Sigma Level calculator) the Sigma Level of the process is 4.4 Sigma Level. After precise calculation keeping each strategy in mind the baseline status can be tabulated as

Table 11: Base line status of Firm for draft gear housing after improvement

Part Name	**Defective piece %**	**Process Yield in %**	**DPMO**	**Sigma Level**
Draft Gear Housing	1.01	99.83	1690	4.4

Now, it is necessary to check the process variation of five week production run (15 February to 15 March 2020) of the casting unit, using statistical quality control i.e. **'np'** chart for no. of defective. The procedure is as follows

All related data can be tabulated as

Table 12: Control chart analysis after improvement

Sr. No.	Name of Month (15 February to 15 March 2020	Sample Size	Defective pieces
1	Week 1	350	3
2	Week 2	350	2
3	Week 3	350	1
4	Week 4	350	1
5	Week 5	350	2
Total		**1750**	**9**

Calculation is done as

ii. Center line of the process **(CL)** = np

Where=proportion defective = $\frac{Total\ No.of\ defectiv\ pieces}{Total\ No.of\ Production\ (Sample\ Size)}$

And n = Sample Size = 350

Now p = $\frac{9}{1750}$ = 0.00514

Then **CL** = 0.00514 x 350 = 1.8

iii. Upper control limit of the process **(UCL)** = np + 3 $\sqrt{npq}$

Where q = 1 - p,

q = 1 – 0.00514 = 0.99486

Now UCL = 350 x 0.00514 + 3 $\sqrt{350\ X\ 0.00514X\ 0.99486}$

UCL = 5.815

iv. Lower control limit **(LCL)**= np - 3 $\sqrt{npq}$

LCL = 350 x 0.00514 – 3 $\sqrt{350\ X\ 0.00514\ X\ 0.99486}$

LCL = - 2.2144

LCL = 0 (If LCL is negative then will taken as zero)

On the basis of above calculation, we can draw the control chart of the current manufacturing process of Draft Gear Housing as

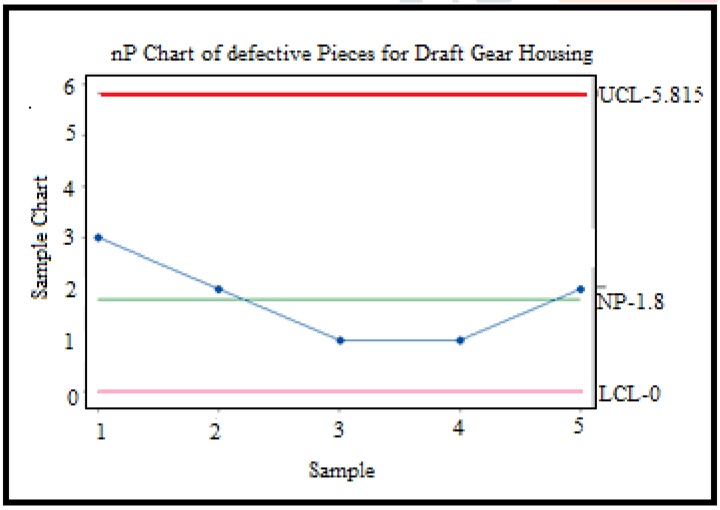

Figure 3: Control chart for Draft Gear Housing after improvement

It is clear from above control chart the all data points falls in between UCL & LCL, so why we can say that Process is in control.

V. RESULTS AND DISCUSSION

The focus of this research is on defect investigation (a reason for casted component rejection) and defect removal from Draft Gear Housing. The Six Sigma tool is used to evaluate data and execute the results using the DMAIC methodology and numerous quality tools (statistical analysis into graphical analysis). Six Sigma quality tools not only reduced casting process faults, but they also improved process knowledge creation (data gathering and interpretation) and application. The generation of process knowledge is a critical component in achieving manufacturing process improvement. The biggest issue related to the present study (foundry) is investigation of the appearance of defect 'scab' in the production of Draft Gear Housing which results into heavy salvage cost or even rejection of casting. The Pareto chart in this study shows that the scab flaw is responsible for 44.6 percent of the problem. All of the causes are highlighted after additional investigation using cause and effect analysis. When clay percentage is kept between 10% and 12%, scabbing defects are reduced significantly. In the current study, the DPMO at the start of the project was 6597, and the process yield was 99.34%. The sigma level for computed DPMO and process yield was 4.0.After investigating the root cause of defects and reducing them, the current DPMO is 1690, and the process yield is 99.83 percent, resulting in a sigma level of 4.4.

VI. Conclusion

During the globalization period, the casting industry has had a difficult problem in producing high-quality products at a reasonable cost and delivering them to customers within the specified lead time. With its DMAIC methodology, the Six Sigma programmer is a potent approach for dealing with this type of quality problem situation. It determines the root cause of faults and eliminates them in order to improve customer satisfaction. The current study uses the Six Sigma approach and DMAIC technique to try to reduce the 'scabbing' fault as well as the casting product 'Draft Gear Housing' rejection rate in the foundry sector. Simultaneously, there is a prospect for improvement in terms of removing other potential flaws. According to the outcomes of this study, the percentage of casting rejection has decreased from 4.17 percent to 1.01 percent.

The firm's Sigma Level has grown from sigma level 4.0 to sigma level 4.4, which is significant.

In addition, the cost of scrap has been decreased as a result of this. In addition, the following are some of the benefits of implementing Six Sigma:

I. complete organizational participation
II. proper guidance of the officials and the uplifting of the people for play a part in the six sigma enhancement are initiated
III. Improved communication among team members

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