Spatial analysis of draft gear of Railway Wagon by using Six Sigma Approach

Abhishek Kumar[1], Sunita Rajbhar[2]

[1]M.Tech Scholar, Department of Mechanical Engineering, S.R. Institute of Management and Technology Lucknow

[2]Assistant Professor, Department of Mechanical Engineering, S.R. Institute of Management and Technology Lucknow

Abstract:- 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 present work investigates the effect of a crack on the modal frequency of a draft pad. Initially, the first five mode shapes of a healthy draft pad and the first seven mode shapes of healthy draft gear considering compressed draft pads are determined using the finite element approach. A mathematical model of the draft pad is formulated to predict the effect of the crack on its modal frequency. A semi-elliptical shaped crack is modelled in the lateral and longitudinal direction of the draft pad. It is observed that if the crack lies in the zone of minimum modal displacement, then the frequency drop is minimal, and if the crack lies in the zone of maximum modal displacement, then the frequency drop is significant. Various damage scenarios are simulated by varying the width and aspect ratio of the crack in order to identify its effect on the modal frequency. It is seen that if the aspect ratio is varied while the crack's width is maintained constant, then the frequency drop is linear, whereas if the crack's width is varied while the aspect ratio is maintained constant, then the frequency drop is parabolic. This study provides a tool for monitoring exciting frequencies of draft gear and shows how each modal frequency is affected by the crack due to parameters like aspect ratio, crack width, and crack location/orientation.

Keywords: Six Sigma, Draft gear, wagon, DMAIC, Pareto

I. Introduction

The requsite to accuire business excellence in casting industry assumes the management commitment to develop and deliver perfect solutions, product or services, to promote "zero defect"(Eger et al., 2018) and first time right production philosphy.

Joseph M Juran tell about the definition of quality fell into two keys areas, higher quality products had a larger number of features which filled with the requirements of the consumer and also had lesser number defects.(Yong & Wilkinson, 2010) In today's global tough marketplace, the need of customers are forever high as they require improved quality of products and services but are like to pay less for their requirement. The longitudinal dynamics of freight wagons largely depends on the dynamics of draft gear and consequently the draft pad(s). Draft gear is a key part of auto couplers in freight wagons, as they function like a cushioning device absorbing shocks in the form longitudinal forces arising due to train operations like accelerating or braking. The draft gear (RF-361) under consideration is manufactured by Miner Enterprises Inc., USA. It is normally used in open hopper/coal wagons and bulk commodity wagons. Freight wagons in Indian Railways are loaded with RF-361 draft gear. The various components of the draft gear illustrated in Fig. 1a are six draft pads with a top follower, three shoes, and a wedge. The draft pad consists of a rubber compound sandwiched between two steel plates and is perfectly bonded to them. All these components are assembled in housing with the three shoes arranged circumferentially around the wedge. The wedge and shoes operate between the top follower and the draft gear housing. The applied forces reach the draft pads through the wedge and shoes. Each pad

has an ultra-high-capacity natural rubber spring package to absorb the high longitudinal forces arising due to operations like acceleration and/or braking and also due to changes in track topography. These forces, being repetitive
in nature, accelerate the damage to the draft pads in the presence of defects. These draft pads, when used in damaged conditions, cause the longitudinal forces to be transmitted to the wagon, which compromises the safety of the laden goods. 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.
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

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 (**CSFs are not the objective of the organization, but are the actions and processes that required by the organization to achieve the organization's goals in the best possible way**),

In this research paper the tries to explain that foundry process has many conjugated and composite processes that require skill and caution to ensure refine quality of sand casting.(Furgał & Cygan, 2009) In foundry operation final quality of casting, also affected by many process variables. In this situation attention is given towards process knowledge in foundries to increase productivity by reducing sand casting defects. Process command is the identification of procedure variables, their assembly approach, and approach and examine system to find out the varying process variables that are analogous with product for specific casting in foundries. In nut shell Six Sigma change knowledge into opportunities for business enhancement and it is aimed on elimination of defects through operation that highlights process understanding, measuring and process enhancement.(Furgał & Cygan, 2009) The purpose of this paper is to elaborate Six Sigma process in a casting industry, that could enhance the green sand casting process in a foundry by reducing the casting defects. The target was to investigate the kind of variables influenced this evolution and the relative weight of critical success factors as the process developed.

The DMAIC (Define, Measurement, Analyze, Improve, and Control)-based Six Sigma methodology is carry out to upgrade the green sand casting process and has made the process more sturdy to quality variations. Analysis of various critical process variables of the melt shop is also carried out with the help of Taguchi's (Chen & Brahma, 2014)method of experimental design. The proposed approach revamp control factors, drive in superior quality and stability of the green sand castings process, which give away to diminish the casting defects and enhancing the Sigma level of the industry.(Kumar et al., 2013)

This article restricting the scope to a single product alternatively of focusing on all of the company's products. Pareto diagrams are utilize to recognize the product that has the topmost scrap percentage and the product that is scrapped most routinely. The company's yearly data for scrap are collected, and the part with the greatest scrap percentage is find out using Pareto diagrams. Figure 9 shows the scrap percentage of different parts. From the Pareto diagram, BBC5500UN is selected for the project because this part has a high production rate. Although the study could have aimed on numerous other defects, this one uses a Pareto diagram to recognize the most general reasons that products are scrapped.

In this case study, DMAIC (Study et al., 2011) based Six Sigma approach is applied to maximize the process variables of foundry. For the conformation of experiment, 500 (total of ten tests) components were produced and only 28 components were defective. It can be observed from the verification test results that the rejection percentage of defects of the casting process was highly reduced by the optimal arrangement of process variables. From the above results, it is demonstrated that the casting variables were optimized and minimum percentage of casting defect figures was obtained.

suggest how continuous improvement can be achieved in practice using Six Sigma methodology in a manufacturing organization. To achieve the improvement quality issues should be recognized in an efficient way. By applying six sigma methodologies the solution comes with many more profits not only for the organization but also for the other elements which involved in the proper functioning.

Further explained the concept of Six Sigma as, it forms the platform for fast growing and streamlined production. Six Sigma enhance the productivity and reduce the quality variance across all the manufacturing firms. (Solanki & Desai, 2020)This study has scruitinized using quality tools like Pareto analysis, Cause and Effect analysis, 5- why analysis and scatter diagram. The study was related to the products of an automobile firm and find some of the critical process through DPMO calculation, Process efficiency and various six sigma levels.

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 rising 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 analysed 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 degrees°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 below300º, 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 +/- 10º 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.

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 week Improve – three week Control – three week

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:

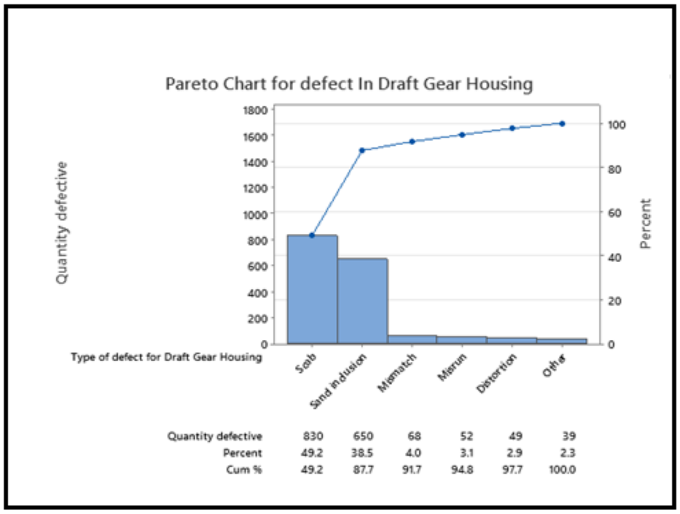

Figure 1: Pareto diagram for draft gear housing defect

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

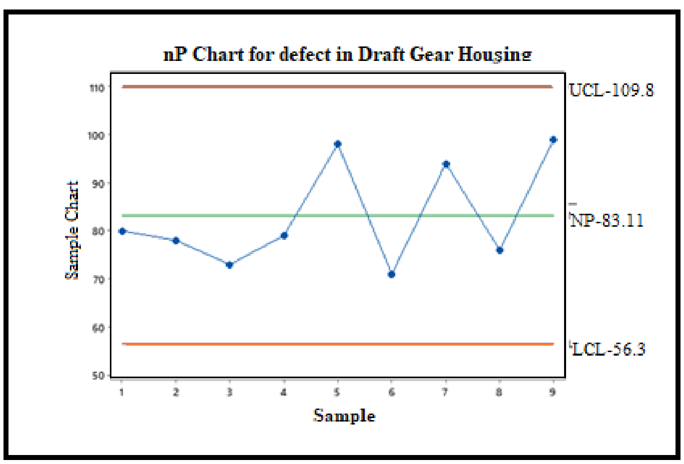

Figure 2: Control chart for production of Draft Gear Housing

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

i. 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 $\sqrt{350\ X\ 0.00514 X\ 0.99486}$

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

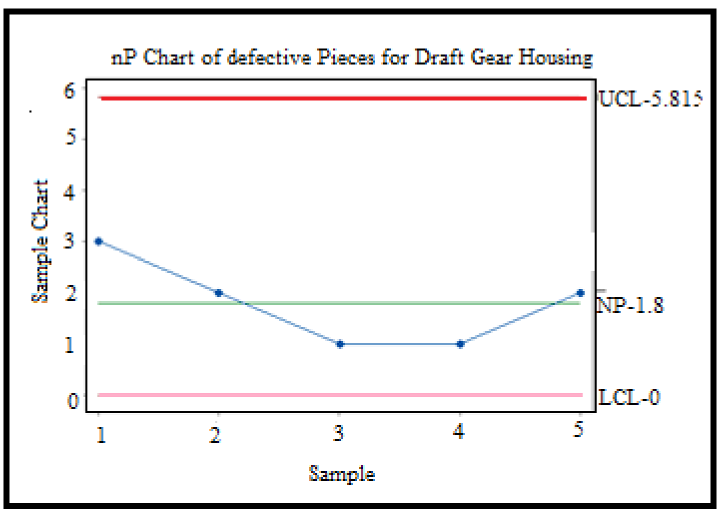

Figure 3: Control chart for Draft Gear Housing after improvement

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.

RESULT & 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.

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

REFERENCES:

1) Čampulová, M., Veselík, P., & Michálek, J. (2017). Control chart and Six sigma based algorithms for identification of outliers in experimental data, with an application to particulate matter PM10. *Atmospheric Pollution Research*, *8*(4), 700–708. https://doi.org/10.1016/j.apr.2017.01.004
2) Chauhan, P. (2019). *Analysis of Casting Defects and Yield Improvement Through Simulation A Case of Cast Iron Straight Parallel Edges*. *5*(November 2018), 994–998.
3) Chen, J. C., & Brahma, A. R. B. (2014). Taguchi-based six sigma defect reduction of green sand casting process: An industrial case study. *Journal of Enterprise Transformation*, *4*(2), 172–188. https://doi.org/10.1080/19488289.2013.860415
4) Chong, Z. L., Khoo, M. B. C., & Castagliola, P. (2014). Synthetic double sampling np control chart for attributes. *Computers and Industrial Engineering*, *75*(1), 157–169. https://doi.org/10.1016/j.cie.2014.06.016
5) Coskun, A., Oosterhuis, W. P., Serteser, M., & Unsal, I. (2016). Sigma metric or defects per million opportunities (DPMO): The performance of clinical laboratories should be evaluated by the Sigma metrics at decimal level with DPMOs. *Clinical Chemistry and Laboratory Medicine*, *54*(8), e217–e219. https://doi.org/10.1515/cclm-2015-1219
6) Dangi, V., & Malik, S. (n.d.). *Casting Defect Reduction in Foundary Shop Using DMAIC Approach*. *IX*(Vii), 1464–1477.
7) *Dissertation on Reducing The Defects in Casting of Piston Using Six Sigma (DMAIC Approach) Master of Technology Mechanical Engineering (Machine Design) by Chandra Shekhar Mr . Rajesh Kaushik < Mechanical Engineering > DECLARATION* (Issue June). (2019).
8) Eger, F., Coupek, D., Caputo, D., Colledani, M., Penalva, M., Ortiz, A., Freiberger, H., & Kollegger, G. (2018). Zero defect manufacturing strategies for reduction of scrap and inspection effort in multi-stage production systems. *Procedia CIRP*, *67*, 368–373.

https://doi.org/10.1016/j.procir.2017.12.228

9) Furgał, G., & Cygan, R. (2009). Quality problems root cause identification and variability reduction in casting processes. *Archives of Foundry Engineering*, *9*(1), 13–16.
10) Ganganallimath, M. M., Patil, S. D., Gijo, E. V., Math, R. B., & Hiremath, V. (2019). Application of Taguchi-based Six Sigma method to reduce defects in green sand casting process: A case study. *International Journal of Business and Systems Research*, *13*(2), 226–246. https://doi.org/10.1504/IJBSR.2019.098666
11) Gavriluță, A. (2017). Analysis of a Production System With the Help of Lean Manufacturing Tools. *TEHNOMUS - New Technologies and Products in Machine Manufacturing Technologies*, 88–93.
12) Girmanová, L., Šolc, M., Kliment, J., Divoková, A., & Mikloš, V. (2017). Application of Six Sigma Using DMAIC Methodology in the Process of Product Quality Control in Metallurgical Operation. *Acta Technologica Agriculturae*, *20*(4), 104–109. https://doi.org/10.1515/ata-2017-0020
13) *IMPROVING PRODUCTIVITY USING LEAN SIX-SIGMA*. (n.d.). 1–4.Journal, I., & Volume,
14) G. S. (2014). *Utilization of six sigma (DMAIC) Approach for Reducing Casting Defects*. *2*(6), 1065–1075.
15) Kumar, S., Satsangi, P. S., & Prajapati, D. R. (2013). Improvement of Sigma level of a foundry: A case study. *TQM Journal*, *25*(1), 29–43. https://doi.org/10.1108/17542731311286414
16) Kumaravadivel, A., & Natarajan, U. (2013). Application of Six-Sigma DMAIC methodology to sand-casting process with response surface methodology. *International Journal of Advanced Manufacturing Technology*, *69*(5–8), 1403–1420. https://doi.org/10.1007/s00170-013-5119-2
17) Lei, C., Liu, J., Dong, L., & Ma, W. (2019). Influence of Draft Gear Modeling on Dynamics Simulation for Heavy-Haul Train. *Shock and Vibration*, *2019*. https://doi.org/10.1155/2019/2547318
18) Malek, J., & Desai, D. (2015). Reducing rejection/rework in pressure die casting process by application of dmaic methodology of six sigma. *International Journal for Quality Research*, *9*(4), 577–604.
19) Modi, V. K., & Desai, D. A. (2016). Status of Six Sigma and Other Quality Initiatives in Foundries Across the Globe. *International Journal of Applied Industrial Engineering*, *4*(1), 65–84. https://doi.org/10.4018/ijaie.2017010104
20) Ouyang, L. Y., & Wu, S. J. (1994). Prediction Intervals for an Ordered Observation from a Pareto Distribution. *IEEE Transactions on Reliability*, *43*(2), 264–269. https://doi.org/10.1109/24.295005
21) Parkash, S., & Kaushik, V. (2011). LogForum ISO 9001 QMS IN SPORTS GOODS MANUFACTURING INDUSTRY. *Scientific Journal of Logistics*, *7*(4), 1–16. *PDF.js viewer.pdf*. (n.d.).
22) Pranavi, K. C., Scholar, M. T., & Pradesh, A. (2019). *REDUCING THE DEFECTS OF MANGANESE STEEL CASTING BY IMPLEMENTATION OF*. *6*(6), 674–683.
23) Prasad, K. G. D., Subbaiah, K. V., & Padmavathi, G. (2012). Application of six sigma methodology in an engineering educational institution. *International Journal of Emerging Science*, *2*(2), 222–237.
24) Raisinghani, M. S., Ette, H., Pierce, R., Cannon, G., & Daripaly, P. (2005). Six Sigma: Concepts, tools, and applications. *Industrial Management and Data Systems*, *105*(4), 491–505. https://doi.org/10.1108/02635570510592389
25) Singh, A. (1961). Couplers and Draft Gears for Indian Railways. *Journal of the Institution of Locomotive Engineers*, *51*(282), 519–554. https://doi.org/10.1243/jile_proc_1961_051_047_02
26) Smętkowska, M., & Mrugalska, B. (2018). Using Six Sigma DMAIC to Improve the Quality of the Production Process: A Case Study. *Procedia - Social and Behavioral Sciences*, *238*, 590–596. https://doi.org/10.1016/j.sbspro.2018.04.039
27) Solanki, M., & Desai, D. (2020). Competitive advantage through Six Sigma in sand casting industry to improve overall first-pass yield: a case study of SSE. *International Journal of Lean Six Sigma*, *12*(3), 477–502. https://doi.org/10.1108/IJLSS-03-2020-0032
28) Srinivasan, K., Muthu, S., Devadasan, S. R., & Sugumaran, C. (2014). Enhancing effectiveness of shell and tube heat exchanger through six sigma DMAIC phases. *Procedia Engineering*, *97*, 2064–2071. https://doi.org/10.1016/j.proeng.2014.12.449
29) Stankalla, R., Chromjakova, F., & Koval, O. (2019). A review of the Six Sigma belt system for manufacturing small and medium-sized enterprises. *Quality Management Journal*, *26*(2), 100–117. https://doi.org/10.1080/10686967.2019.1580119
30) Study, I. a C., Kumar, S., Satsangi, P. S., & Prajapati, D. R. (2011). *Six Sigma an Excellent Tool for Process*. *2*(9), 1–10.
31) Wagner, S., Cole, C., & Spiryagin, M. (2021). A review on design and testing methodologies of modern freight train draft gear system. *Railway Engineering Science*. https://doi.org/10.1007/s40534-021-00237-y
32) Wu, Z., & Wang, Q. (2007). An NP control chart using double inspections. *Journal of Applied Statistics*, *34*(7), 843–855. https://doi.org/10.1080/02664760701523492
33) Yong, J., & Wilkinson, A. (2010). *The long and winding road : The evolution of quality management*. *January 2015*, 37–41. https://doi.org/10.1080/09544120120098591