SSRG International Journal of Mechanical Engineering
ISSN: 2348–8360 / https://doi.org/10.14445/23488360/IJME-V10I4P103

Volume 10 Issue 4, 13-20, April 2023

Original Article

Reduction Analysis of Welding Defects using Lean Six Sigma and DMAIC Application – A Case Study

S. Nallusamy[1*], P.S. Chakraborty[1], G.V. Punna Rao[2]

[1]*Department of Adult, Continuing Education and Extension, Jadavpur University, Kolkata, India*
[2]*Department of Mechanical Engineering, Prakasam Engineering College, Kandukur, Andhra Pradesh, India*

[1*]*Corresponding Author : ksnallu@gmail.com*

Received: 26 February 2023 Revised: 05 April 2023 Accepted: 20 April 2023 Published: 30 April 2023

Abstract - *This research aims to investigate the process of gas tungsten arc welding commonly used in the submersible pump industry. The weld abandons is a noteworthy concern prompting revamp, greater expenses, and in this manner, influencing the conveyance plan of the activity. This research article succeeds in deploying the six sigma Define, Measure, Analyze, Improve, and Control (DMAIC) structure to improve the action features and assess and eradicate different sources in an operational system referred to in the industry. To implement the fundamental methods in various tasks, best usage instigation of availabilities, variabilities moderations, and maintaining the consistent output six sigma tool is adopted. The root cause analysis of Tungsten Inert Gas (TIG) welding defects and static tools to recognize the potential causes for controlling and supporting a few changes with proposals are specified. The current level of deformity was found to be 15% in stator rejections for the period of one month. After implementing the proposal, the overall defect was expected to reduce.*

Keywords - *Welding, Non-Destructive Test, Lean six sigma, DMAIC, Stator.*

1. Introduction

The research work manages the utilization of the six sigma DMAIC technique in a pump manufacturing industry which gives a system to recognize, measure, and dispense with wellsprings of variety in different working procedures to upgrade the activity factors [1, 2]. The six sigma technique is to enhance the primary working procedures, improve the usage of entire assets, reduce the varieties, and maintain the output at the expected level.

1.1. Non-Destructive Testing

In general, the fabricated materials by TIG welding could be undergone quality and reliability tests with a minimum of two the inspections like visual, liquid penetrant, ultrasonic, and radiography testing [3, 4].

1.2. Visual Inspection

Visual inspection is presumably the most underestimated and frequently abused strategy for welding assessment. In view of its effortlessness and the nonattendance of complex gear, the capability of this strategy for examination is regularly disparaged. Visual examination of welding can frequently be the most straightforward to perform and is normally the most economical to lead, shown in Figure 1, sourced from Google. Whenever done accurately, this kind of investigation can regularly be a very powerful strategy for keeping up worthy welding quality and averting welding issues [5]. Numerous territories inside the welding activity can be checked and assessed by this strategy for review. Similarly, the other three tests of non-destructive testing such as liquid penetrate testing, ultrasonic testing, and radiography testing, as shown in Figure 2, Figure 3, and Figure 4, respectively, could be done for the welded materials to assess the welding quality [6-8].

1.3. Six Sigma

Six Sigma is a type of lean tool to develop a new methodology for the existing production system to enhance the overall output to represent Total Quality Management (TQM). The proposed TQM model for manufacturing process improvement and the philosophy of TQM are explained in detail in the following Figure 5. Six Sigma driver is added to enhance the quality of the current manufacturing system to cover all the TQM mechanisms [9-11].

2. Methodology

DMAIC is a shut-circle process that wipes out ineffective advances, regularly centres around new estimations, what's more, connects innovation for ceaseless improvement.

Execution of the DMAIC Methodology took place in five stages, as illustrated before, and built up at Motorola [12]. Issue distinguishing proof and definition happens in characterizing stage. In the wake of recognizing principle forms, their execution is determined in the measuring stage with the assistance of information accumulation. The main drivers of the issue are discovered in the investigation stage. Answers for tackling issues and executing them are in the improving stage. Improvement is kept up in the charge stage represented in Figure 6.


Fig. 1 Visual inspection for TIG welding

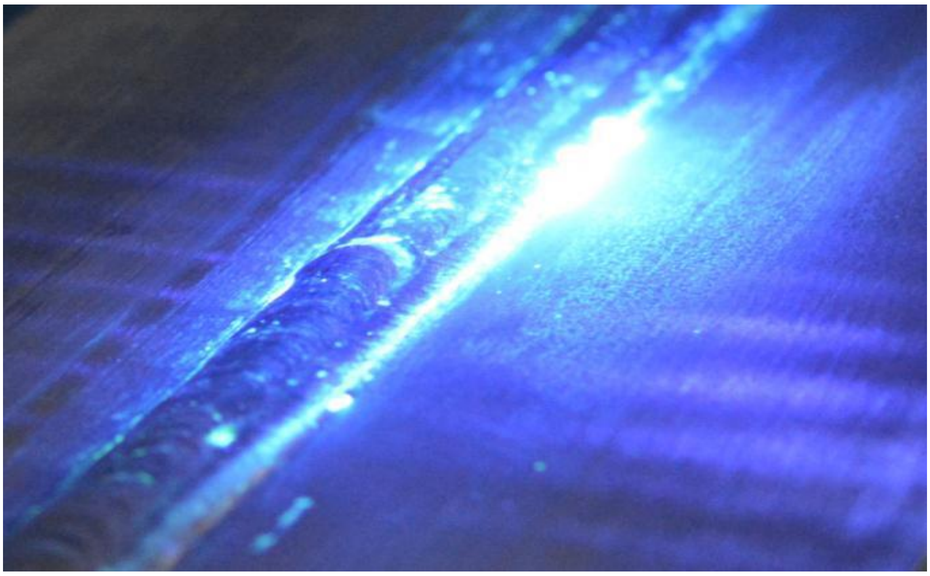
Fig. 2 Liquid penetrate testing for welding

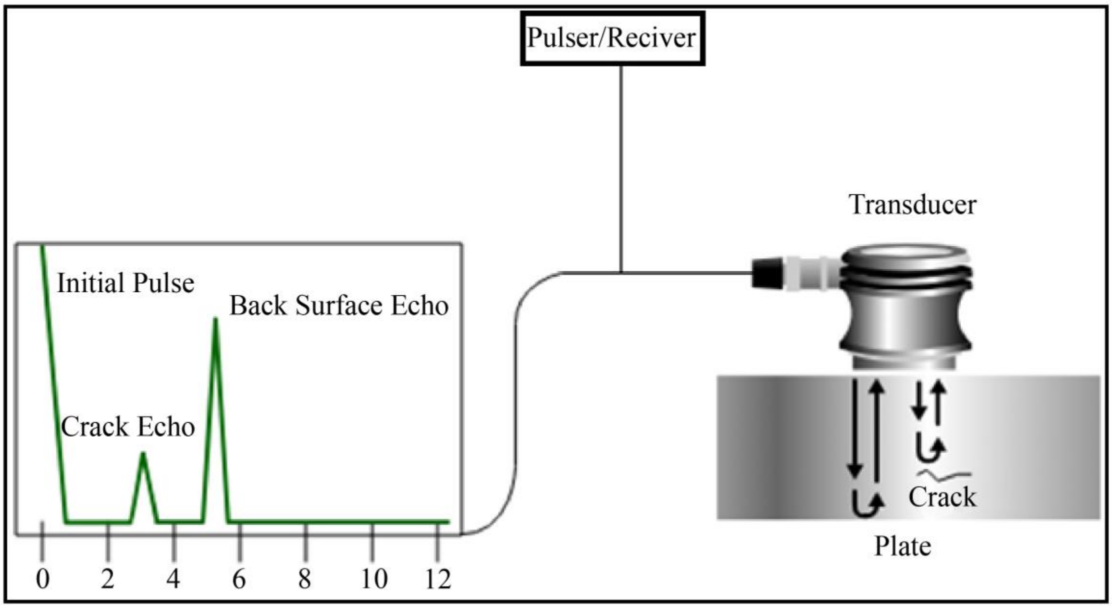

Fig. 3 Ultrasonic testing for welding

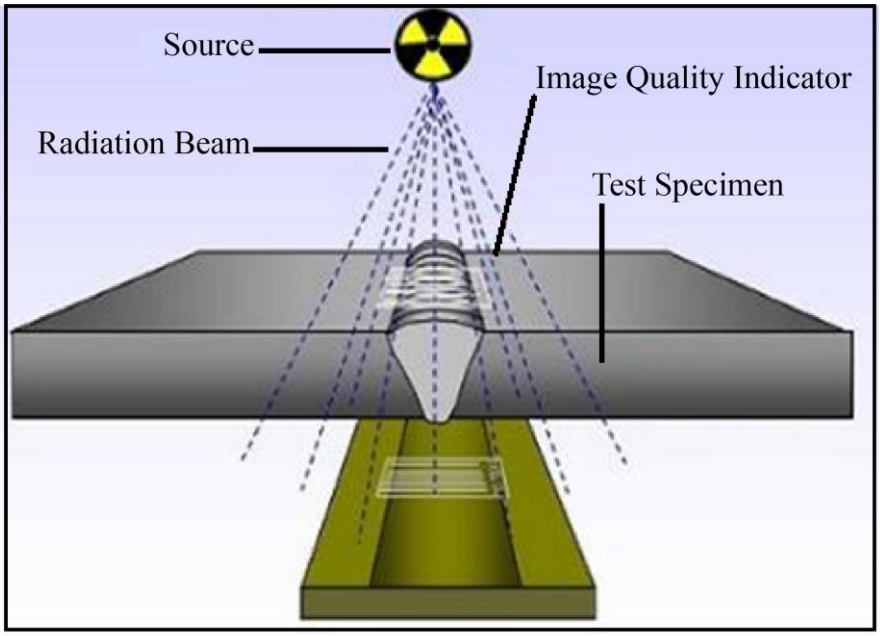

Fig. 4 Radioactive testing

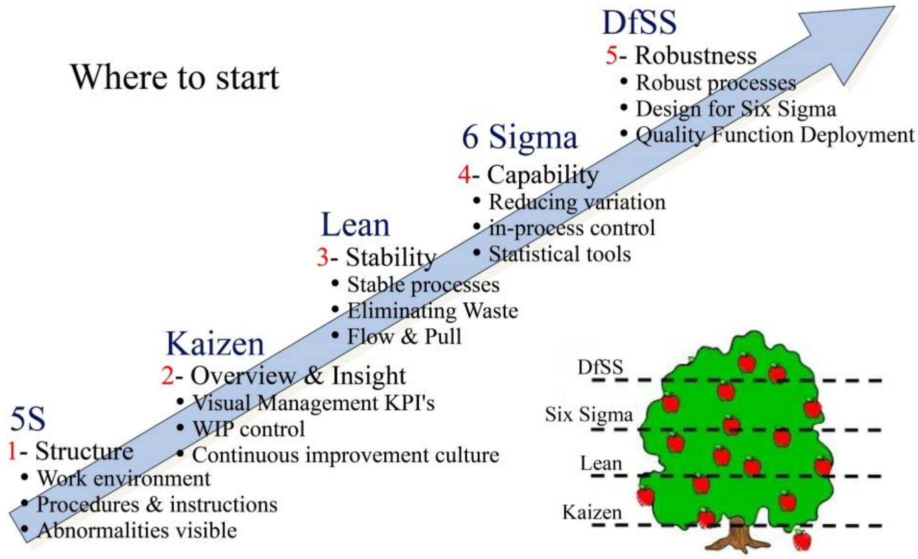

Fig. 5 TQM model chart

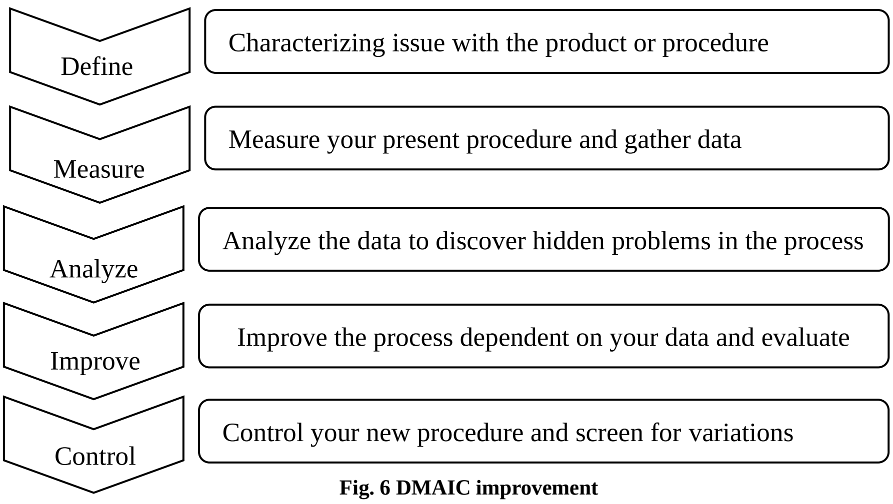

Fig. 6 DMAIC improvement

3. Results and Discussion

3.1. Define Stage

In this stage, characterize the reason for the project, scope, what's more, the process foundation for both inward and outside clients. There are some alternate apparatuses that are utilized in characterizing stages like Suppliers, Inputs, Processes, Outputs, Customers (SIPOC), customer voice, and an organization value size, as shown in Figure 7. Characterize the issue and extension the work exertion of the venture group [13]. The suitable sorts of issues have boundless degree and scale, from worker issues to issues with the creation procedure or publicizing. The industry faces many problems in that defects discontinuity of a portion of weld bead in TIG welding is the major defect selected based on historical data shown in Figure 8. This Pareto chart represents 74.5% Blind holes, 15.1% Air holes, 5.7% Air cracks, 2.4 Excess cuts, 1.4% surface scare, and 0.8% run out based on this data, 20% of the major problem occurred due to blind holes in the welding area.

3.2. Measure Stage

This stage exhibits the nitty gritty procedure mapping, operational definition, information gathering outline, assessment of the current framework, appraisal of the present dimension of process execution, and so on, shown in Figure 9. The objective of the measured period of a six sigma DMAIC venture is to get as much data as conceivable on the present procedure in order to get it completely. The month with defects is shown in Figure 10.

Supplier	Input	Process	Output	Customer
 Internal Customer 	 Stamping End Ring Insert End Ring Holder Stator Tube Filler Material (ER3012) Argon Gas Tungsten Rod Skew Rod	The Process Diagram is below Fig 8	 Stator	 Stator Winding

Fig. 7 Supplier Input Process Output Customer (SIPOC)

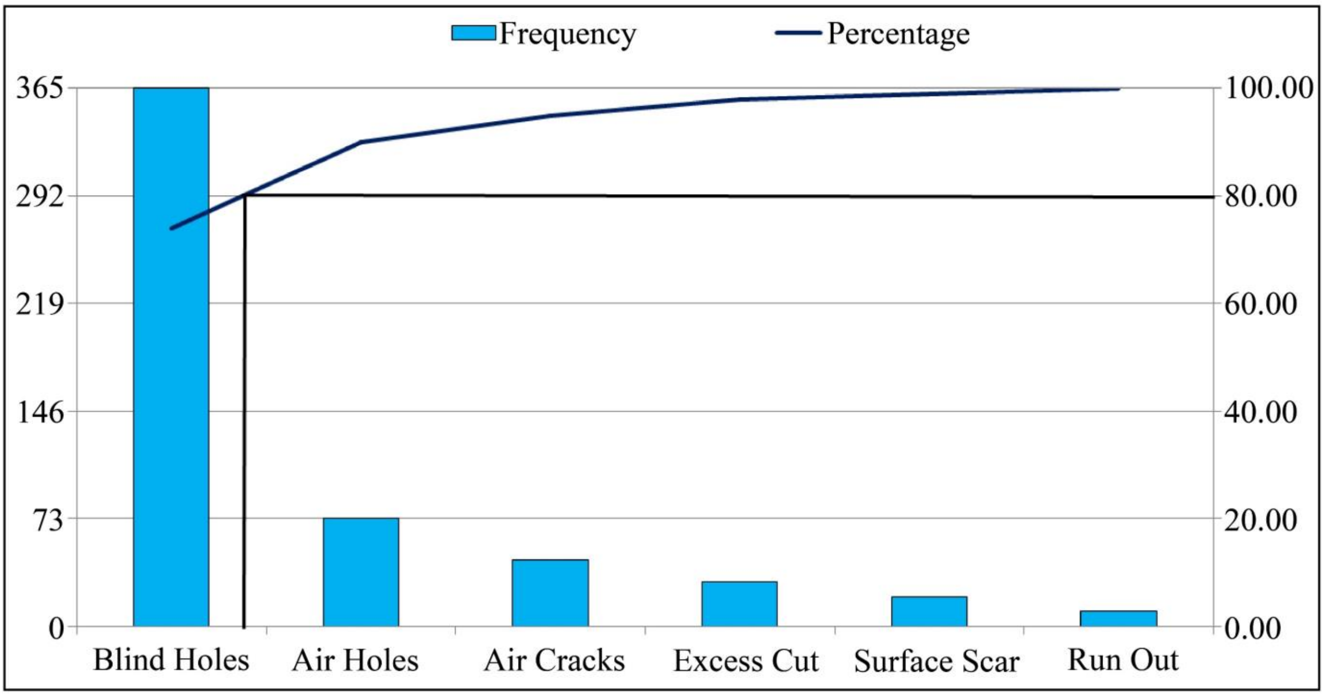

Fig. 8 Pareto chart for historical data

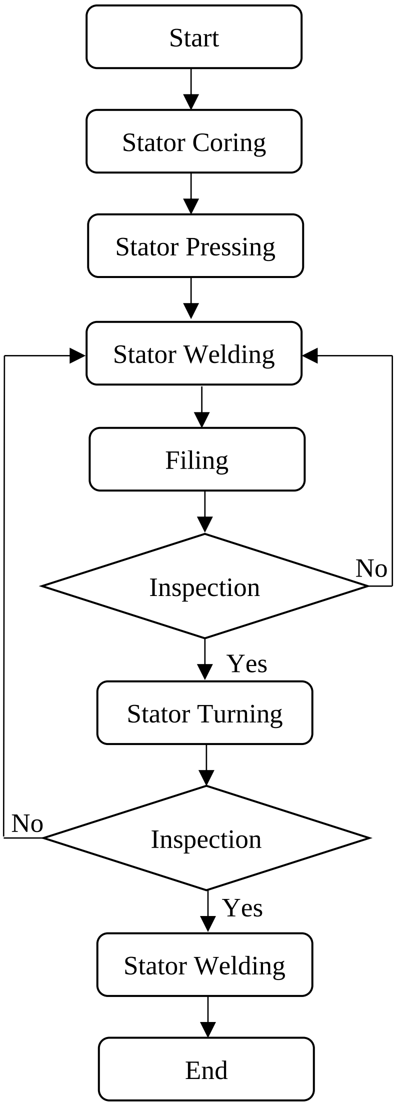

Fig. 9 Process mapping

There are 4 TIG welding machines on the shop floor; each machine operates in the same sequence. Stator welding causes problems in the Stator tube and enduring inserts joint area welding defect. Past 1-month rejections are collected. The stator tube welding's initial position has been marked; the directions of the weld area should be marked to identify the weld defects in 360 degrees.

3.3. Investigation of Root Cause

The main root causes of the issues that occurred for the non-improvement output in the existing manufacturing system could be identified with the proper tool [14-16]. Through proper investigations, the methodology, types of equipment, and processes could be analyzed to find the reason for defects in a product, as shown in Figure 11. The neck level of the cause for the defect is known as the root cause of the issue, as shown in Figure 12.

Some underlying driver investigation approaches are intended more for recognizing genuine main drivers than others; some are increasingly broad critical thinking procedures, and others just offer help for the main driver examination centre action. By getting to be familiar with the underlying driver investigation tool kit, we will have the capacity to apply the proper strategy or apparatus to address a particular issue.

3.4. Analyze Stage

The third period of the DMAIC procedure incorporates the meaning of the primary driver of the imperfections and analysis for using the root cause of one of the apparatuses, for example, the fishbone outline organizing the significance or criticality of each cause utilizing instruments, for example, the FMEA, WHY-WHY investigation.

Using a concentration chart, data collected has been stratified, representing the most clustered area where the frequency of defects is high. Based on these observations, data shows that concentration is highly required in the top-side joint area, shown in Figure 13.

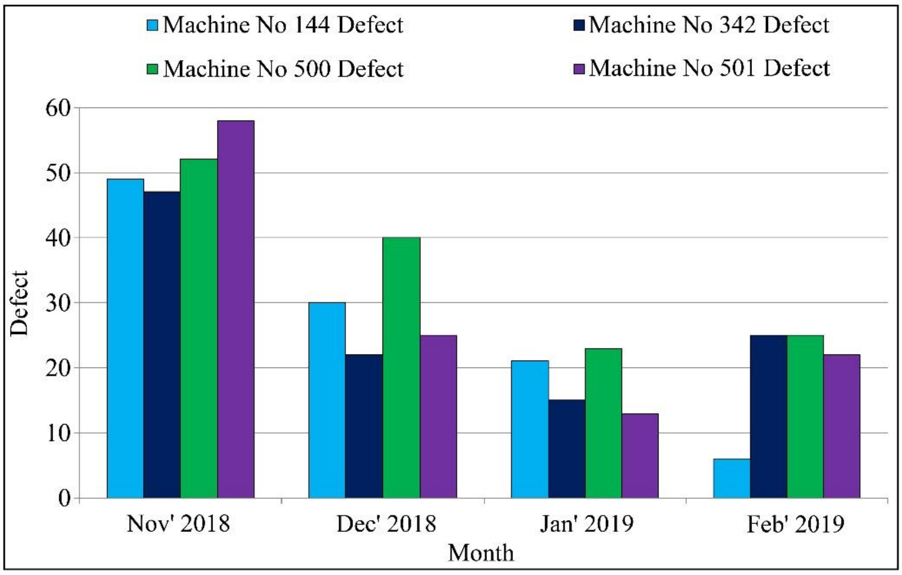

Fig. 10 Month wise defect level

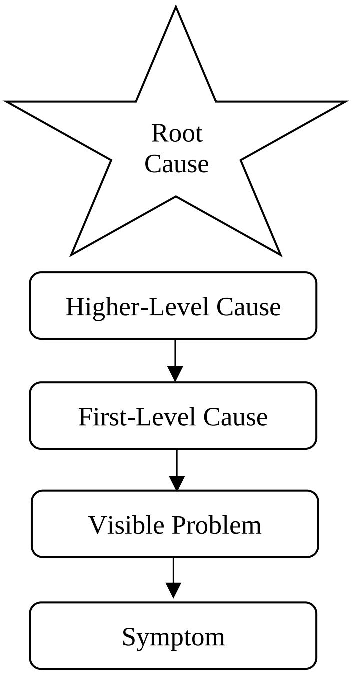

Fig. 11 Root cause analysis

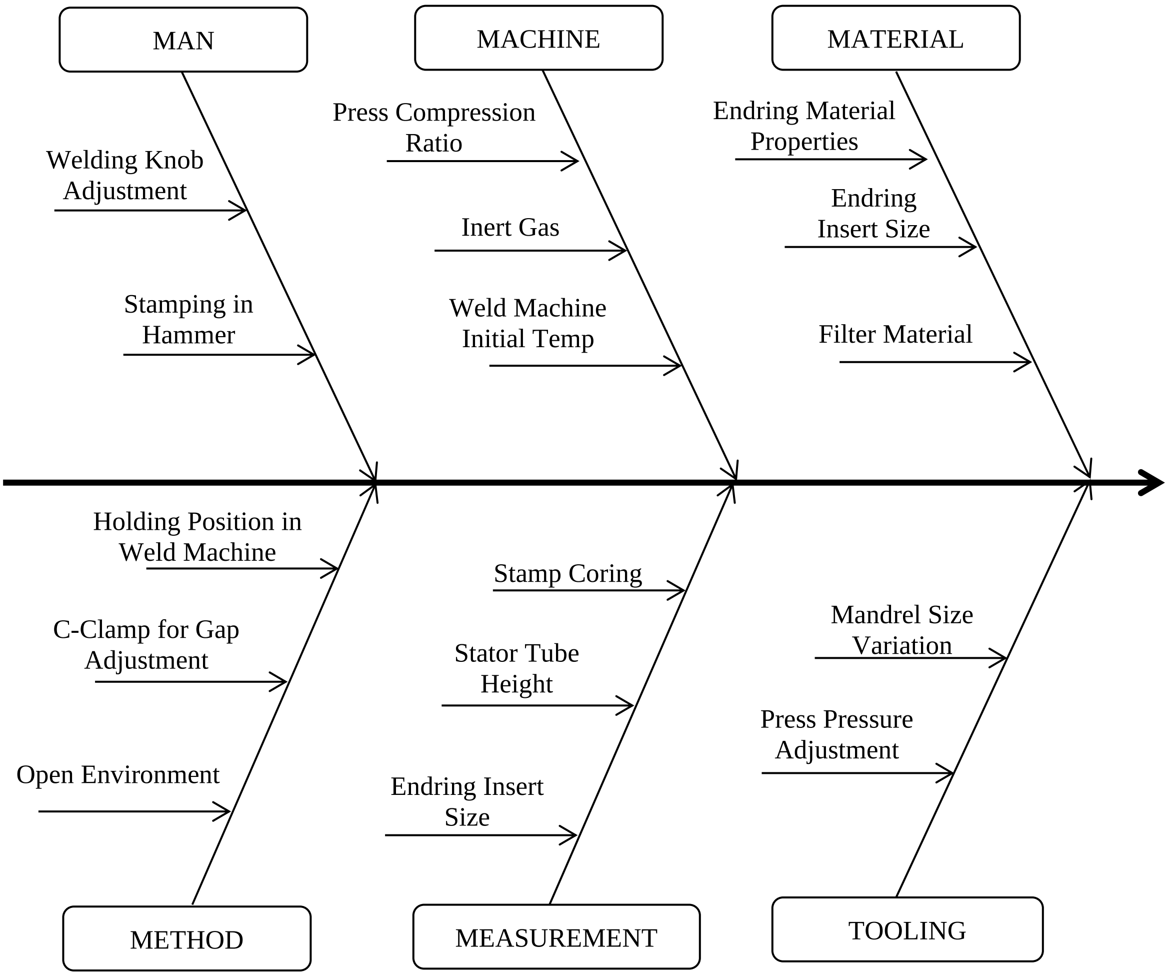

Fig. 12 Cause and effect diagram

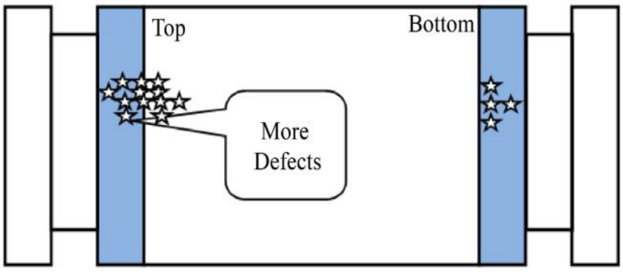

Fig. 13 Defect concentration diagram

For future invitations, we have developed a hypothesis in a circular connection chart based on the angles of the defect, as shown in Figure 14. It gave a clear idea of the initial stage of welding causing the high level of defects; also, defects are diffracted based on defect size and area, which shows defects are based on knob adjustment in the welding machine for the gap between the filler rod and stator tube.

3.5. Detailed Process Map

The procedure begins with the welding of long creases; furthermore, roundabout creases in the activity, and along these lines, the NDT discovers any deformities amid welding. A detailed stream diagram appears in Figure 15. both how it works and how well it works.

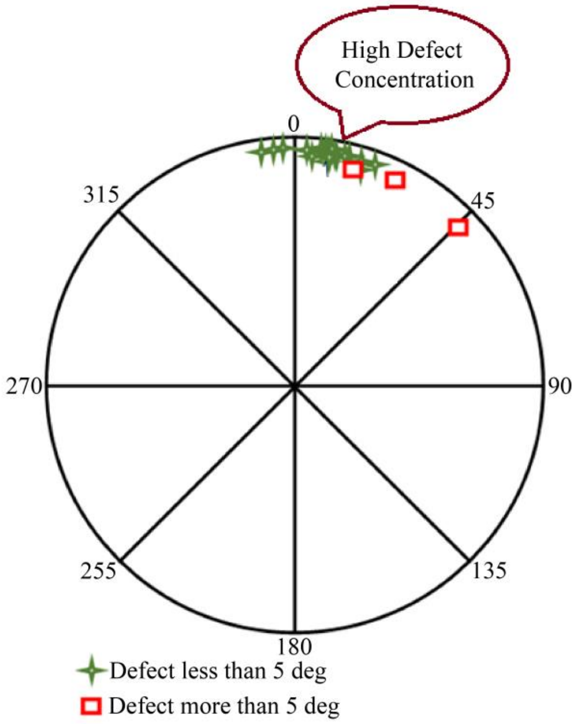

Fig. 14 Concentration chart for the defect

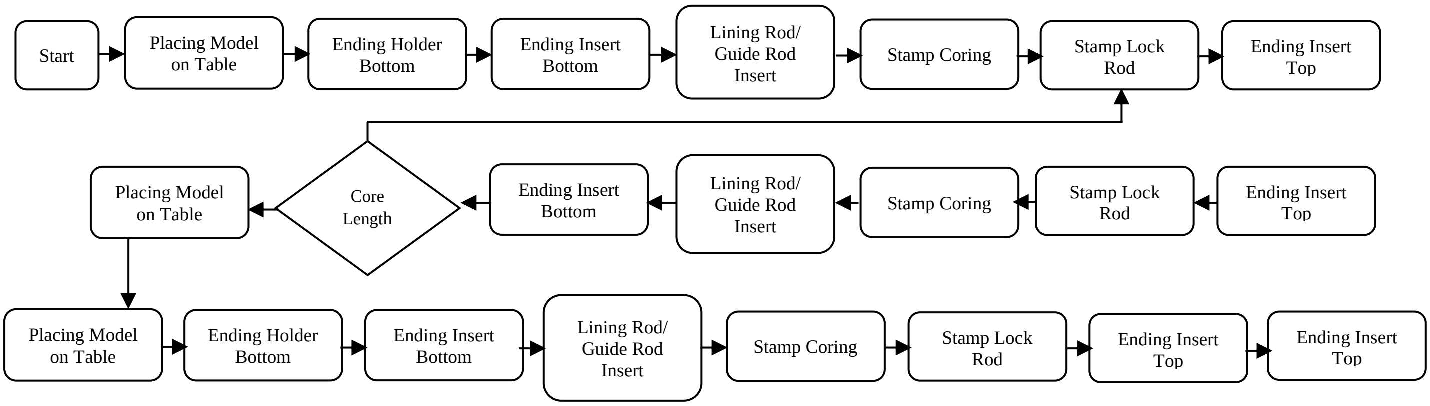

Fig. 15 Detailed Process Map

3.6. Improve Stage

The objectives of this stage are to choose the issue arrangement, perceive the dangers and actualize chosen arrangement. The improvement must research vital information dependent on conceptualizing to make the best arrangement. The stage centres around completely understanding the top causes distinguished in the Analyze stage, aiming to either control or dispose of those causes to accomplish leap-forward execution. This progression utilizes inventive approaches to find better approaches to improve, less expensive or quicker. Impromptu creations in the process are done altogether to keep the factors inside as far as possible.

Identified the major cause for the blind hole's defect in the stator tube, so PTC cero3.0 design is proposed for the special gauge, which seats the top portion in the machine bed and bottom blade in the gauge to stator ring. So the operator can easily adjust the knob to the proper position without requiring high knowledge or experience. The proposed diagram of the gauge design is shown in Figure 16.

3.7. Control Stage

The last period of DMAIC is controlling, which is the stage in which we guarantee that the procedures keep on functioning admirably, produce wanted yield results, and keep up quality dimensions. This is tied in with holding the increases which the venture group has accomplished. DMAIC's Control stage is tied in with supporting the progressions made in the improvement stage to ensure enduring outcomes. The best controls are those that require no checking (irreversible item or process configuration changes). Controls are required to guarantee that the enhancements are kept up after some time. The altered procedure is exposed to a vigil at standard interims of time to guarantee that the key factors don't demonstrate any inadmissible varieties.

Fig. 16 Proposed Model of the Gauge Design

4. Conclusion

The operational Six Sigma system was chosen to take care of various issues in a welding procedure. This Six Sigma improvement system, viz., DMAIC venture, demonstrates that the execution of the organization is expanded to a superior dimension with respect to improvement in clients' (both interior and outer) fulfilment, adherence to conveyance plans, advancement of explicit techniques to update and revamp a procedure to decrease or take out blunders, surrenders; improvement of progressively productive, able, solid and reliable assembling process and all the better by and large procedure execution, formation of persistent improvement in efficiency. The current level of deformity was found to be 15% in stator rejections for the period of one month. After implementing the proposal, the overall defect was expected to reduce.

References

[1] G. V. S. S. Sharma, and P. Srinivasa Rao, "A DMAIC Approach for Process Capability Improvement an Engine Crankshaft Manufacturing Process," *Journal of Industrial Engineering International*, vol. 10, pp. 65-76, 2014. [CrossRef] [Google Scholar] [Publisher Link]

[2] Manish Bhargava, and Sanjay Gaur, "Process Improvement Using Six-Sigma (DMAIC Process) in Bearing Manufacturing Industry: A Case Study," *IOP Conference Series: Materials Science and Engineering*, vol. 1017, 2021. [Google Scholar] [Publisher Link]

[3] Sandeep Kumar Dwivedi, Manish Vishwakarma, and Akhilesh Soni, "Advances and Researches on Non Destructive Testing: A Review," *Materials Today: Proceedings*, vol. 5, no. 2, pp. 3690-3698, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[4] Masoud Shaloo et al., "A Review of Non-Destructive Testing (NDT) Techniques for Defect Detection: Application to Fusion Welding and Future Wire Arc Additive Manufacturing Processes," *Materials*, vol. 15, no. 10, p. 3697, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[5] Anirudh Sampath Madhvacharyula et al., "In Situ Detection of Welding Defects: A Review," *Weld World*, vol. 66, pp. 611-628, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[6] Ana Lopez et al., "Non-Destructive Testing Application of Radiography and Ultrasound for Wire and Arc Additive Manufacturing," *Additive Manufacturing*, vol. 21, pp. 298–306, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[7] S. Nallusamy, "Analysis of Welding Properties in FSW Aluminium 6351 Alloy Plates Added with Silicon Carbide Particles," *International Journal of Engineering Research in Africa*, vol. 21, pp. 110-117, 2015. [CrossRef] [Google Scholar] [Publisher Link]

[8] Yongfeng Song et al., "Nondestructive Testing of Additively Manufactured Material Based on Ultrasonic Scattering Measurement," *Measurement*, vol. 118, pp. 105-112, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[9] Jéssica Galdino de Freitas, and Helder Gomes Costa, "Impacts of Lean Six Sigma over Organizational Sustainability: A Systematic Literature Review on Scopus Base," *International Journal of Lean Six Sigma*, vol. 8, no. 1, pp. 89-108. [CrossRef] [Google Scholar] [Publisher Link]

[10] S. Nallusamy, "A Proposed Model for Sustaining Quality Assurance Using Tqm Practices in Small and Medium Scale Industries," *International Journal of Engineering Research in Africa*, vol. 22, pp. 184-190, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[11] Araman, H., and Saleh, "A Case Study on Implementing Lean Six Sigma: Dmaic Methodology in Aluminum Profiles Extrusion Process," *The TQM Journal*, vol. 35, no. 2, pp. 337-365, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[12] Ilesanmi Daniyan et al., "Application of Lean Six Sigma Methodology Using Dmaic Approach for the Improvement of Bogie Assembly Process in the Railcar Industry," *Heliyon*, vol. 8, no. 3, p. E09043, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[13] Pratima Mishra, and Rajiv Kumar Sharma, "A Hybrid Framework Based on Sipoc and Six Sigma DMAIC for Improving Process Dimensions in Supply Chain Network," *International Journal of Quality & Reliability Management*, vol. 31, no. 5, pp. 522-546, 2014. [CrossRef] [Google Scholar] [Publisher Link]

[14] Rao G V P, S. Nallusamy, and M. Rajaram Narayanan, "Augmentation of Production Level Using Different Lean Approaches in Medium Scale Manufacturing Industries," *International Journal of Mechanical Engineering and Technology*, vol. 8, no. 12, pp. 360-372, 2017. [Google Scholar] [Publisher Link]

[15] John B, and Kadadevaramath, "Improving the Resolution Time Performance of An Application Support Process Using Six Sigma Methodology," *International Journal of Lean Six Sigma*, vol. 11, no. 4, pp. 663–686, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[16] E. V. Gijo, Raniprasad Palod, and Jiju Antony, "Lean Six Sigma Approach in an Indian Auto Ancillary Conglomerate: A Case Study," *Production Planning & Control*, vol. 29, no. 9, pp. 761-772, 2018. [CrossRef] [Google Scholar] [Publisher Link]