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Improvement in the Productivity and Process Efficiency of TIG Welding Process Using Six Sigma (DMAIC) Techniques – A Case Study

M. Aravindh, S. Rajkumar, T. Mohamed Azarudeen*
Department of Mechanical Engineering, Thiagarajar College of Engineering, Madurai, Tamil Nadu, India

ABSTRACT

The purpose of this paper is to demonstrate the methodology in implementation of Six Sigma techniques and to make a suggestion for the process efficiency and productivity improvement in a TIG welding process in small scale fabrication industry. The importance of Six Sigma DMAIC (Define-Measure- Analyze-Improve-Control) methodology is illustrated in a well-defined structured manner which provides an agenda to recognize, calculate and eradicate sources of variation of issues to optimize the operation variables, progress and quality performance in a well control plans. In this work case study for fabricating refrigeration stand using TIG welding process and to improve the process performance (process yield) of the critical operational process, leading to better utilization of resources, and maintains consistent quality of the process and the associated output of the welding process where the existing system is intensely observed, classified, prioritized depending upon the basis of type of welding process, type of materials used, working timing of labor, work efficiency. In recent research papers the major works are concentrated on a particular issue as productivity and quality management of TIG welding process and ignoring the wider perception of process efficiency where there exists a necessity of having a detailed work to cover up all the issues, challenges associated with it. To overcome the problems in process efficiency a detailed, described and structured methodology of Six Sigma (DMAIC) techniques will be the right tool to provide suggestion for the improvement in process efficiency in TIG welding.

Keywords: process efficiency, productivity, quality function deployment, Six Sigma (DMAIC) techniques, SWOT analysis TIG welding

****Corresponding Author***
E-mail: m.aravindhmech27@gmail.com

INTRODUCTION

Among the welding process the usage of TIG welding is more common nowadays since it is used to weld components of different material and to join very thin section of aluminum, stainless steel, and nonferrous metal such as copper, magnesium. Gas Tungsten Arc Welding (GTAW) also called as Tungsten Inert Gas (TIG) welding is a welding process which highly reactive at room temperature uses a constant current power, tungsten electrode to produce arc for weld and filler metal [1]. The components of TIG welding are good conductors of heat and produce exceptionally good quality welds and used to weld thin sections of stainless steel and nonferrous metals. GTAW finds application in producing high quality joints in nuclear, aircraft and automation industries. In industries strategic implication of continuous improvement is concentrated at an enormous rate to improve production quality and productivity by reducing potential reliability problems early in the

development cycle, manufacturing industries are using some statistical tools for aligning and evaluating possible failures in the system, design, process or service in the form of Six Sigma [2]. Sigma is a statistical concept that represents the amount of variations present in a process relative to customer requirements or specifications. "Six Sigma" refers to business philosophy of focusing on continuous improvement by understanding the customer needs instituting proper measurement methods and analyzing the business processes [3]. Six Sigma is a well-structured data driven methodology for eliminating defects, waste, quality control problems of all kinds in manufacturing, management, service delivery etc. [4]. Six Sigma advocates a methodology (DMAIC) for reducing the TIG welding defects and it is one among the concepts considered as a methodology for improvement in process capabilities and an innovative approach to continuous process improvement with a major contribution in quality improvement, labor efficiency and a systematic framework in building a structure for improvement in the overall company's current business system [5]. Six Sigma has become a much broader umbrella and has evolved as a strategic approach in most of the manufacturing and service organizations for quick response which becomes major challenges created in the competitive business world [6]. Today Six Sigma has become a comprehensive management and a process of embedding quality awareness at every step of production or service while targeting the end customer [7]. The process of continuous improvement is a never-ending process which keeps on motivating for better result and best potential outputs. Any companies or an enterprise can challenge their competitive companies with high quality products at low price with higher customer satisfaction. Six Sigma has cultivated a quality awareness program in the business environment and as a result targeting 99.99927% defect free manufacturing which results in better, faster and cost-effective process, also results in reducing variation, and defects [8]. A set of tools and techniques for the process development which Focuses on quality improvement with a technique of DMAIC with an acronym of define, measure analyze, improve, control [9]. In welding process improving process parameters influencing performance such as process yield, critical operational, utilization of resources, and quality and the associated output of the welding process are considered with variation and defects in the process Variation is the enemy of the business and it questions the quality of the process. Improving predictability means that the prediction of required output [10].

RESEARCH PROBLEMS AND OBJECTIVES

A research problem is to define in a well determined manner which has to represents a researcher work in a particular area to find out the optimal solution for the defied problem, i.e., the context of a given environment and course of action are optimally attained satisfying the objective. In this study the research problem is to suggest and implement the Six Sigma DMAIC method for the process improvement of TIG welding in a small fabricating company for the fabrication of refrigeration stand and other small components in an industry to reduce the process variation. Detailed research problems are as follows.

In general, process efficiency of small-scale industries in TIG welding cannot match up to the expectation of higher productivity due to less utilization of resources and defects in welding products and process. The defects in TIG welding process includes contamination, oxidation defect, lack of fusion, craters, lack of penetration, porosity, tungsten inclusion, etc. From these defects, the more

commonly occurring defects are lack of fusion, lack of penetration and porosity. It also leads to wastage in the working time of labors, decreased process efficiency and a decrease in the productivity. The problem formulation also deals with the educational qualification of welders and the inexperience of welders, which leads to highly decreased process efficiency. The modern era of competitiveness urges to make to bring their products and services to world class level. For that, along with various tools Six Sigma is becoming popular in India. Considering specific need, implementing Six Sigma concepts to make process effectively; the main objectives of this Research work are:

- Understand the need of Six Sigma in an organization.
- Reduce the rejection of defective product and to increase the process sigma level of that particular process.
- Evaluate and compare Six Sigma and the existing way of working.
- Improvement in the process performance of the critical operational process in TIG welding.
- Enhancing better utilization of resources.
- Decreases variations and maintains consistent quality of the process output.
- Improves the process variation that provides suggestion and solution in optimizing process parameters.
- To minimize of the oxidation defect, lack of fusion, lack of penetration in TIG welding process.

To achieve the above-mentioned objectives DMAIC methodology has been used in present research.

METHODOLOGY

The implementation of Six Sigma has been usually done using DMAIC approach. DMAIC is a closed-loop process that eliminates unproductive steps, often focuses on new measurements, and applied technology for continuous improvement. Implementation of DMAIC Methodology having five phases as outlined earlier and established at Motorola. Problem identification and definition takes place in define phase. After identifying main processes, their performance is calculated in measure phase with the help of data collection. Root causes of the problem are found out in analysis phase. Solutions to solve problem and implementing them are in improve phase. Improvement is maintained in control phase DMAIC is a closed-loop process that eliminates unproductive steps, often focuses on new measurements, and applied technology for continuous improvement. After identifying main processes, their Performance is calculated in measure phase with the help of data collection. Root causes of the problem are found out in analysis phase. Solutions to solve problem and implementing them are in improve phase. Details of each phase is explained in Table 1. Improvement is maintained in control phase in some of the above-mentioned references, the five letters abbreviations are explained as follows:

D: Define, what problem needs to be solved?
M: Measure, What is the capability of the process?
A: Analysis, When and where do defects occur?
I: Improve, How the process capability can be improved?
C: Control, What control can be put in place to sustain the gain?

Define Phase

The focus of this phase is defining the problem that requires solution and ended with clear understanding of scope and evidence of management support in order to guarantee the commitment from stakeholders involved. Apart from that, we identified customer requirements that consisted both internal and external stakeholders. This information was captured in Team Charter for proof of requirement and commitment.

Table 1. *DMAIC details.*

Sl. no	Phases	Details
1	Define (D)	Set project goals and objectives
2	Measure (M)	Measure the defects where they occur
3	Analyze (A)	Evaluate data/information for trends, pattern and root causes
4	Improve (I)	Evaluate data/information for trends, pattern and root causes. Develop, implement and evaluate, Solution targeted at identified root causes
5	Control (C)	Make sure that the problems have been cleared and method is improving

BUSINESS CASE:

This was the first tool used in the Define Phase. A business case is a decision-making tool that formally describes the problem, the benefits, cost, and impact of the project to the environment. The general Information about the project is explained in Table 2 also the Project charter is explained in the Table 3, Where the Goals, risks, assumptions were also mentioned.

Table 2. *General information.*

General information	
Project name	Improvement in the productivity and process efficiency of TIG welding process using Six Sigma (DMAIC) techniques– A Case Study
Organizational unit	Welding shop
Process impacted	Daily performance Reporting
Expected start date	18/12/2017
Expected completion date	26/03/2018

Table 3. *Project character.*

Project charter	
Problem	• Oxidation defect, • Lack of fusion, • Lack of penetration.
Purpose of the project	To increase the productivity in TIG welding process.
Business case	• Improvement in TIG welding process will reduce COPQN on production idle hours, • Delay in delivery of jobs, which will satisfy the customer, which will lead to improvement in quality, production and good products.
Goals	• Design and develop solutions to address the root causes behind welding defects.
Expected deliverables	• Reduction of non-production idle hours. • Reduction of COPQ. • Increase in TIG welding machine Process yield
Risks	Changes to the project scope-project needs to stay focused on root causes behind the source data and not expanding the project in to developing new system requirements for problems with various application.
Constraints	The agency does not have the sufficient budget to allocate any resources for the project. The project team will have direct access to Six Sigma black belt
Assumptions	The project is following a Six Sigma DMAIC approach. The agency has limited experience in doing projects according to this methodology

Measure Phase

It focuses on data collection (based on customer's requirements) and converts them into Critical to Quality attributes (CTQs).

Measure phase involves evaluation of the existing system, assessment of current data involved in TIG welding process. The goal of the Measure phase of a Six Sigma DMAIC project is to get as much information as possible on the current process so as to fully understand both how it works and how well it works. The Data collected in the company is listed in the Table 4.

Table 4. *Data collection.*

Process	Time taken (min)	No of labor	Total time	No. of electrodes
Value set up in meter	5	1	480 mins	0
Hose setup	2			
Torch setup	2			
Gas opening	1			
Pressure setup	30 sec			
Welding of base	6	1		2
Welding of top corner	5			2
Welding of 6 rods	13			3
Welding of leg part	6			3
Total time available for labors (8 hrs shift)		480 min		
Idle time for labors		80 min		
Total no of labors for this process		2 Helper and Welder		
Wage for the helper (8 hrs shift)		Rs. 400		
Wage for the welder (8 hrs shift)		Rs. 600		
Total wage for the labors		Rs. 1000		

Analysis Phase

Cause and Effect Diagram

Root cause analysis is used to address a problem or non-conformance, in order to get the "root cause" of the Problem. It is used here to correct or eliminate the improper supply of shielding gas and prevent the oxidation defect from recurring. Figure 1.

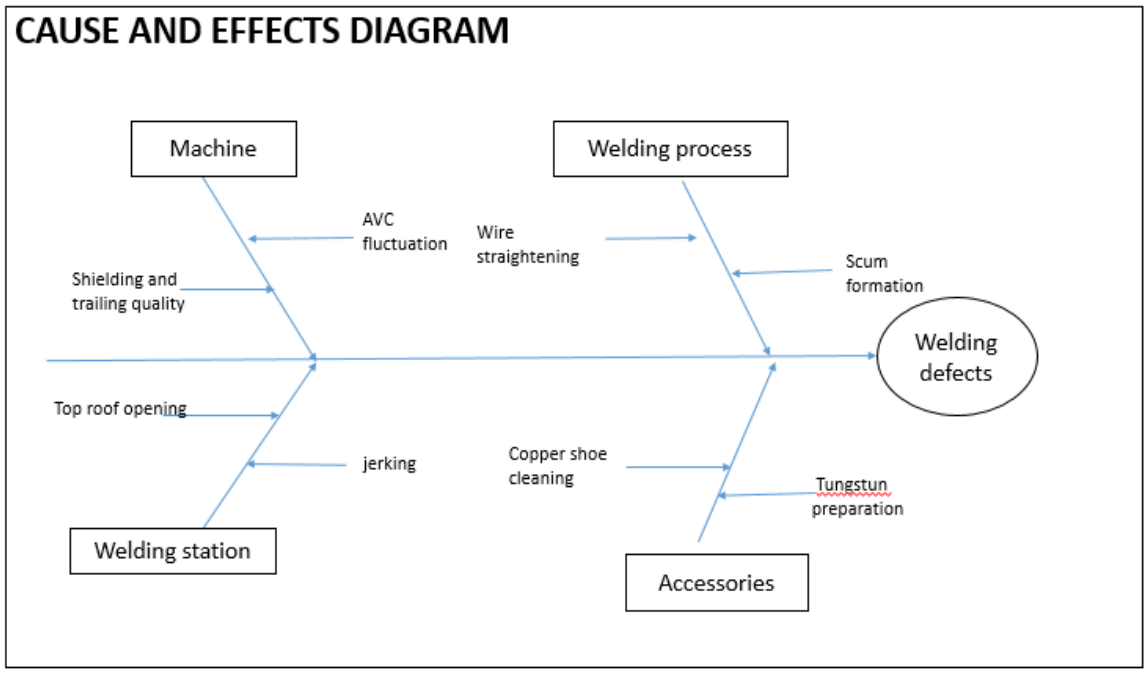

Fig. 1. *Cause and effect diagram (fish bone diagram).*

SWOT Analysis

SWOT analysis is a study undertaken by an organization to recognize its internal strengths and weaknesses, as well as its external opportunities and threats. This SWOT analysis is briefly summarizing in

the Table 5. It is intended to specify the objectives of the project and identify the internal and external factors that are favorable and unfavorable to achieving those objectives.

Table 5. *SWOT analysis.*

Strengths	**Weaknesses**
• Cost effectiveness, reliability and safety makes welding the choicest option • Comparing to other processes such as bolting and riveting, welding provides stronger and lighter products • Scope is widened for material from metal to ceramics	• It requires energy and time-consuming efforts • Welding is not an exact science thus imperfection may occur • Minimization of these welding defects depends on the welder skill • Welding professionals do not come from specialized educational background. This creates a shortage for skilled worker.
Opportunities	**Threats**
• Improving the quality of welds and increasing the efficiency of welding operations might change the negative perception of welding. • An increase in skilled worker and improvements in the industries can prove helpful • Providing more people with requisite training might translate to improvements in the overall quality of outputs	• Inefficiency in the welding process and imperfect finishing contributes to the negative perception of the industries. • Industries that primarily use welding to join products are turning to industrial adhesives which are more agile and stronger tools. • Increasing competitions also threatens welding industries

Improve Phase

QFD

In Improve phase the tool used is QFD. A system for translating customer necessities in to appropriate company requirements at each stage from research and product development to engineering and manufacturing to marketing and distribution. It helps organization to take the voice of the customer and factor their wants and needs in to organization product and process planning. The "House of Quality" matrix is the most recognized form of QFD. It is utilized by a multidisciplinary team to translate a set of customer requirements, drawing upon market research and benchmarking data, into an appropriate number of prioritized engineering targets to be met by a new product design. The customer requirements and the its Prescribed quality characteristics are shown in Table 6.

Table 6. *House of quality.*

Demanded quality	**Quality characteristics**
Reduce defects	Current
Proper supply of shielding gas	Effectiveness
Easy handling to use	Efficiency
Power consumption	Voltage
Good weldability	Size
Low cost	Safety
Durable	Feed and speed
Skill of the worker	Strength
Easy setup	Adaptability

CALCULATION IN HOQ:

Table 7 & Figure 2 explain the relationship values for each quality parameters is explained.

Table 7. *Relationship calculation.*

Max relationship value in row	Relative weight	Weight/importance	Demanded quality	Quality characteristics
9	10.5	9.0	Reduce defects	Current
9	8.1	7.0	Proper supply of shielding gas	Effectiveness
9	7.0	6.0	Easy handling to use	Efficiency
9	3.5	3.0	Power consumption	Voltage
9	7.0	6.0	Good weld ability	Size
1	9.3	8.0	Low cost	Safety
1	8.1	7.0	Durable	Feed and speed
3	8.1	7.0	Skill of the worker	Strength
3	5.8	5.0	Easy setup	Adaptability

Relative weight = (Weight*100)/Sum of weight.
Target value and limit= Σ(relative weight*max relationship value)

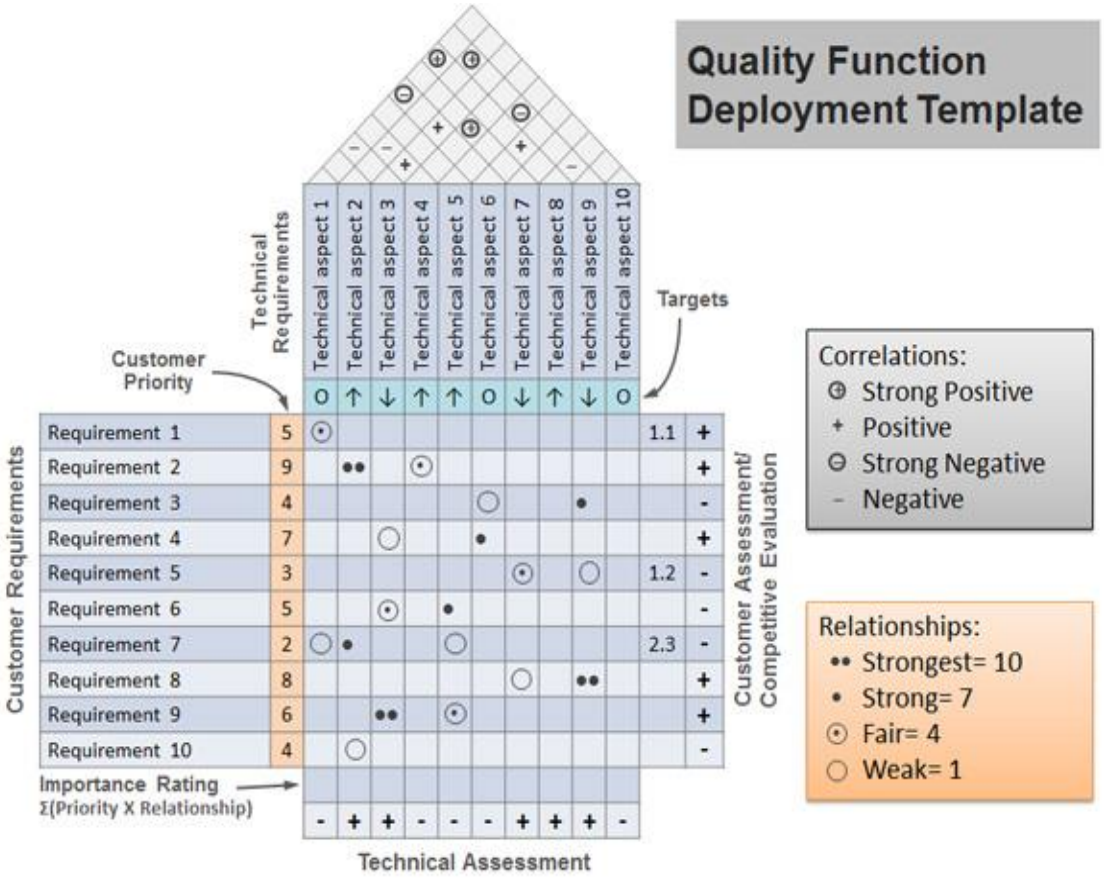

Fig. 2. *House of quality.*

Control Phase

The last phase of DMAIC is control, which is the phase in which we confirm that the processes remain to work well Produce desired output results and maintain quality levels. This is about

holding the gains which have been achieved by the project team DMAIC's Control phase is about sustaining the changes made in the Improve phase to guarantee lasting results. The best controls are those that require no monitoring.

Suggestions for control phase:

- Proper labor utilization.
- Reduction of idle time.
- Proper supply of shielding gas.
- Providing proper safety equipment's.

These are the suggestions we made to the company. But they were not implemented in the company due to less awareness about Six Sigma and time constraints in this project.

For a one day shift of 8 hours including allowances they can produce 15 products. Before the implementation of Six Sigma out of 15 products 3 products were defective.

Existing method process efficiency:

$$Percentage\ of\ \ defect = \frac{Number\ of\ \ defective\ products \times 100}{Total\ no\ of\ \ products}$$

= 3*(100/15) =20%.

Percentage of non-defective products = 80%

Improved method process efficiency:

$$Percentage\ of\ \ defect = \frac{Number\ of\ \ defective\ products \times 100}{Total\ number\ of\ \ products}$$

= 1*(100/15) = 6.67%

Percentage of non-defective products = 93.33%.

After the implementation of Six Sigma, we suggest that the defects get reduced to 1 product from 3 products. As far as in percentage defect it get reduced to 6.67% from 20%. Percentage of non-defective products increases from 80% to 93.33%.

CONCLUSION

Adaptation of DMAIC tool in the small fabrication company helps in improvement of the process efficiency after successful suggestion and implementation of DMAIC Process efficiency improved from 80% to 93.33% Reduction of idle time improved from 80 to 70 min in 8 hrs shift. Labors are utilized effectively in the terms of job enrichment and with high motivation. The percentage of non-defective products is improve from 80% to 93.33%. The percentage of defects id reduced to 6.67% from 20%.Proper training and motivation about the safety, skill, efficiency and effectiveness prompting better profit and Overall process performance is improved thus better weld quality in TIG welding is obtained improvement in reliability and cost savings in terms of rework and avoidance of project overruns.

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