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REDUCTION IN TIG WELDING DEFECTS FOR PRODUCTIVITY IMPROVEMENT USING SIX SIGMA

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Abstract- In this paper study of Gas Tungsten Arc Welding (GTAW) process used for Aerospace application, the material used is Maraging steel (MDN250).The weld defects are a major concern leading to rework, higher costs and thus affecting the delivery schedule of the job. The process starts with Welding of long seams and circular seams in the job, and subsequently carrying out the NDT to find any defects during welding. A number of defects are being observed in the welding Process. Defects in welding may be found out in two methods, i.e. by Radiographic Tests and by Ultrasonic Tests. The paper deals with an application of Six Sigma DMAIC (Define–Measure-Analyze-Improve-Control) methodology in an industry which provides a framework to identify, quantify and eliminate sources of variation in an operational process in question, to optimize the operation variables. Six Sigma improves the process performance of the critical operational process, leading to better utilization of resources, decreases variations & maintains consistent quality of the process output.

Keywords: Gas Tungsten Arc Welding (GTAW), Maraging Steel, Non-Destructive Testing(NDT), Six Sigma, DMAIC Methodology.

I. INTRODUCTION

Gas Tungsten Arc Welding (GTAW), also known as tungsten inert gas (TIG) welding is a process that produces an electric arc maintained between a nonconsumable tungsten electrode and the part to be welded. The heat-affected zone, the molten metal, and the tungsten electrode are all shielded from atmospheric contamination by a blanket of inert gas fed through the GTAW torch. Inert gas (usually Argon) is inactive or deficient in active chemical properties. The shielding gas serves to blanket the weld and exclude the active properties in the surrounding air. Inert gases, such as Argon and Helium, do not chemically react or combine with other gases. [1] The paper deals with an application of Six Sigma DMAIC (Define–Measure-Analyze-Improve-Control) methodology in an industry which provides a framework to identify, quantify and eliminate sources of variation in an operational process in question, to optimize the operation variables. Six Sigma improves the process performance of the critical operational process, leading to better utilization of resources, decreases variations & maintains consistent quality of the process output.

A. Inputs of Welding

i. Raw material
ii. Resources
iii. Process parameters
iv. Skill and accuracy
v. Weld edge geometry

i) Raw Material

Maraging steel are iron-nickel alloys designed to combine high strength with good fracture toughness the properties are achieved through the age hardening pf low carbon martensite that forms when the steels are cooled from the austenitizing temperature. The martensite forms independently of cooling rate and is relatively soft but when it aged at approximately 900^0F. it hardens considerably through precipitation of intermetallic compound. From the weldability point of view, the most important feature of maraging steel is the fact that they are relatively soft after cooling austenizing temperatures. this means that heat affected zones are softened by heat of welding with the result that the residual stress are lowered and there is less tendency for hydrogen cold cracking. a post weld ageing treatment strength of the joint close to the plate strength and the toughness of heat affected zone usually matches that of the plate. Filler wire used to weld maraging steel have the composition very similar those of the base plates[2].

II. NON-DESTRUCTIVE TESTING(NDT)

TIG welded MDN250 materials are inspected for its reliability and quality. Generally fabricated parts undergo two means of inspection.

i. Visual Inspection
ii. Liquid Penetrant Test
iii. Ultrasonic Testing
iv. Radiography Testing

A. *Ultrasonic Testing*

Ultrasonic Testing (UT) uses high frequency sound energy to conduct examinations and make measurements. Ultrasonic inspection can be used for flaw detection/evaluation, dimensional measurements, material characterization, and more. A typical UT inspection system consists of several functional units, such as the pulser/receiver, transducer, and display devices.

B. *Radiography Testing*

Radiographic Testing is primarily used to find sub-surface flaws in materials. High voltage X-ray machines produce X-rays whereas gamma rays are produced from radioactive isotopes such as iridium 192. The chosen radiation source is placed close to the material to be inspected and the radiation passes through the material and is then captured either on film or digitally. The choice of which type of radiation is used (X-ray or gamma) largely depends on the thickness of the material to be tested and the ease of access to area of inspection. Laboratory Radiographic Testing are undertaken for fabricated materials, foundries, pipe work fabricators, pressure vessel manufacturers and many other users [3].

III. SIX SIGMA

Six Sigma is considered as a methodology of implementing TQM. Six Sigma is an innovative approach to continuous process improvement and a TQM methodology. Since quality improvement is the prime ingredient of TQM, adding a Six Sigma program to the company's current business system covers almost all the elements of TQM. Six Sigma has become a much broader umbrella compared to TQM [4].

A. DMAIC Methodology

DMAIC is a closed-loop process that eliminates unproductive steps, often focuses on new measurements, and applied technology for continuous improvement as shown in Fig.1 [5].

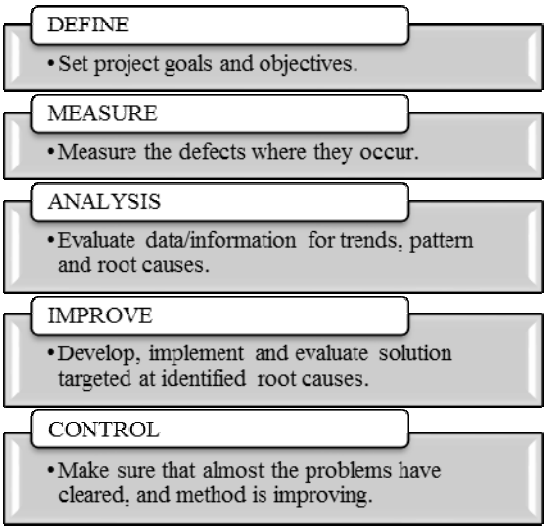

Fig.1: Roadmap to Six Sigma

Implementation of DMAIC Methodology took place in 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 [6].

1) Define Phase

In this phase, define the purpose ofproject, scope and process background for both internal and external customers. There are a different tools which is used in define phase like SIPOC, Voice of Customer and Quality Function deployment. DEFINE the problem and scope the work effort of the project team. The description of the problem should include the pain felt by the customer and business as well as how long the issue has existed. Hence, identify the customer(s), the project goals, and timeframe for completion. The appropriate types of problems have unlimited scope and scale, from employee problems to issues with the production process or advertising. Regardless of the type of problem, it should be systemic part of an existing, steady-state process wherein the problem is not a one-time event, but has caused pain for a couple of cycles.

Table 1: Supplier Input Process Output Customer (SIPOC)

SUPPLIER	INPUT	PROCESS	OUTPUT	CUSTOMER
MIDHANI	Filler wire	Wire mfg. process	Good quality filler wire	L&T
Fabrication Shop	Welder & machines	Welding	Defect free weld	NDE
QC & NDE	Operators & machines	NDE Techniques	Evaluation (No. of defects)	Fabrication Shop
Shop & WE	Plan & Welder	Repair Welding	Repair cleared weld	Machine shop

2) Measure Phase

This phase presents the detailed process mapping, operational definition, data collection chart, evaluation of the existing system, assessment of the current level of process performance, etc. 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. Repair Data collected shown in below chart.

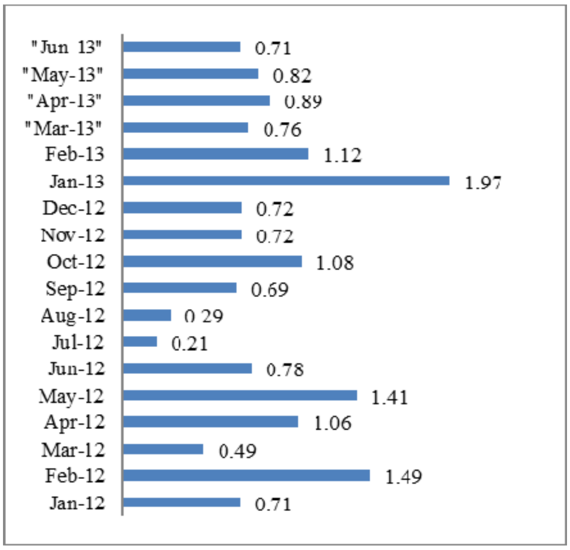

Fig. 2: Month wise Defect Level.

3) Analyze Phase

The third phase of the DMAIC process includes the definition of the main causes of the defects and a root cause analysis using one of the tools such as the fishbone diagram prioritizing the importance or criticality of each cause using a tools such as the FMEA,WHY-WHY Analysis.

i) Detail Process Analysis

The process starts with Welding of long seams and circular seams in the job, and subsequently carrying out the NDT to find any defects during welding. Detail activity Flow chart shown in Fig.

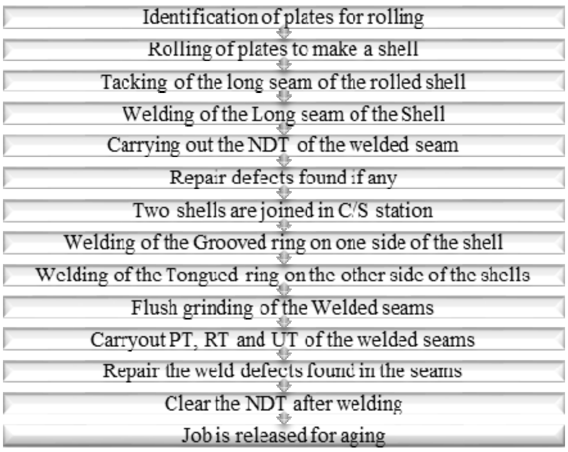

Fig. 3: Activity Flow Chart

ii) Root-Cause Analysis:

Root-Cause Analysis (RCA) is a method that is used to address a problem or non-conformance, in order to get the "root cause" of the problem. It is used so we can correct or eliminate the cause, and prevent the problem form recurring. Root-Cause analysis is a completely separate process to incident management and immediate corrective action, although they are often completed in close proximity.RCA is simply the application of a series of well known, common sense techniques which can produce a systematic, qualified and documented approach to the identification, understanding and resolution of underlying causes.

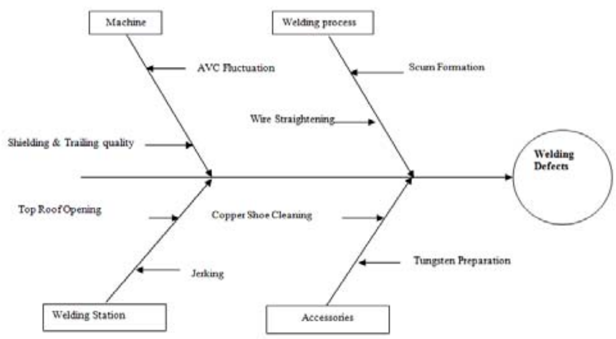

Fig. 4: Cause and effects diagram for Welding Defects.

iii) Failure Mode Effect Analysis (FMEA):

Failure Modes and Effects Analysis (FMEA) is methodology for analyzing potential reliability problems early in the development cycle where it is easier to take actions to overcome these issues, thereby enhancing reliability through design. FMEA is precisely an analytical methodology used to ensure that potential problems have been considered and addressed throughout the product and process development cycle. A process or a design should be analyzed first before it is implemented and also before operating a machine the failure modes and effect must be analyzed critically. In this work, process failure mode and effect analysis is done on general TIG welding process.

a) *Severity***:**

Determining all failure modes based on the functional requirements and their effects. Examples of failure modes are: Electrical short-circuiting, corrosion or deformation. A failure mode in one component can lead to a failure mode in another component; therefore each failure mode should be listed in technical terms and for function. Hereafter the ultimate effect of each failure mode needs to be considered. A failure effect is defined as the result of a failure mode on the function of the system as perceived by the user. In this way it is convenient to write these effects down in terms of what the user might see or experience. Examples of failure effects are: degraded performance, noise or even injury to a user. Each effect is given a severity number (S) from 1 (no danger) to 10 (critical). These numbers help an engineer to prioritize the failure modes and their effects. If the sensitivity of an effect has a number 9 or 10, actions are considered to change the design by eliminating the failure mode, if possible, or protecting the user from the effect. A severity rating of 9 or 10 is generally reserved for those effects which would cause injury to a user or otherwise result in limitation.

Table 2: Severity rating

Rating	Meaning
1	No effect
2	Very minor(only noticed by discriminating customers)
3	Minor (affects very little of the system, noticed by average customers)
4,5,6	Moderate (most customers are annoyed)
7,8	High (causes a lot of primary function; customers are dissatisfied)
9,10	Very high and hazardous(product becomes inoperative)

b) *Occurrence:*

In this step it is necessary to look at the cause of a failure mode and the number of times it occurs. This can be done by looking at similar products or processes and the failure modes that have been documented for them in the past. A failure cause is looked upon as a design weakness. All the potential causes for a failure mode should be identified and documented. Again this should be in technical terms. A failure mode is given an occurrence ranking (O), again 1–10. Actions need to be determined if the occurrence is high (meaning > 4 for non-safety failure modes and > 1 when the severity-number from step 1 is 1 or 0). This step is called the detailed development section of the FMEA process. Occurrence also can be defined as %. If a non-safety issue happened less than 1%, we can give 1 to it. It is based on product and customer specification.

Table 3: Occurrence rating

Rating	Meaning
0.1	No known occurrences on similar products or processes
0.2,0.3	Low (relatively few failures)
0.4,0.5,0.6	Moderate (occasional failures)
0.7,0.8	High (repeated failures)
0.9,1	Very high (failure is almost inevitable)

c) *Detection:*

When appropriate actions are determined, it is necessary to test their efficiency. In addition, design verification is needed. The proper inspection methods need to be chosen. First, we should look at the current controls of the system, that prevent failure modes from occurring or which detect the failure before it reaches the customer. Hereafter one should identify testing, analysis, monitoring and other techniques that can be or have been used on similar systems to detect failures. From these controls an engineer can learn how likely it is for a failure to be identified or detected. Each combination from the previous 2 steps receives a detection number (D). This ranks the ability of planned tests and inspections to remove defects or detect failure modes in time. The assigned detection number measures the risk that the failure will escape detection. A high detection number indicates that the chances are high that the failure will escape detection, or in other words, that the chances of detection are low.

Table 4: Detection rating

Rating	Meaning
10	Certain ,fault will be caught on test
20	Almost certain
30	High
40,50,60	Moderate
70,80	Low
90,100	Fault will be passed to customer undetected

After these three basic steps, risk priority numbers (RPN) are calculated.

d) Risk Priority Number (RPN)

RPN play an important part in the choice of an action against failure modes. They are threshold values in the evaluation of these actions. After ranking the severity, occurrence and detect ability the RPN can be easily calculated by multiplying these three numbers: RPN = S × O × D. This has to be done for the entire process and/or design. Once this is done it is easy to determine the areas of greatest concern. The failure modes that have the highest RPN should be given the highest priority for corrective action.

Table 5 : CAUSE EFFECT MARIX

Category	Sr. No.	Cause(X)	Severity Scale : 1-10	occurrence (0-1)	Detection Scale: 10-100	Score
Welding Station	1	Top roof closing	1	0.2	10	2
	2	Shaft Alignment	5	0.1	10	5
	3	Humidity	5	0.1	50	25
	4	Jerking	5	0.5	50	125
	5	Cleanliness	8	0.8	20	128
Accessories for Setup & Welding	1	Offset Clamps & offset rings	1	0.1	10	1
	2	Purging pipeline condition	5	0.1	20	10
	3	Wire Straightening unit & Cleaning	7	0.2	20	28
	4	Quality of burr wheel & polish wheel.	4	0.2	40	32
	5	Cleaning & quality of liners & rollers.	6	0.2	40	48
	6	Gas Cylinder Purity.	10	0.1	50	50
	7	Wire Wheel quality.	6	0.3	50	90
	8	White cloth for cleaning.	5	0.5	40	100
	9	Cu-Shoes Cleaning & leakage Check.	8	0.4	40	128
	10	Method of cleaning of Developer.	7	0.5	50	175
	11	Tungsten Electrode preparation (Angle & Finish)	8	0.6	60	288
Welding Boom Related	1	Torch Angle.	8	0.1	20	16
	2	Water Tank cleaning.	3	0.5	20	30
	3	Torch Condition.	7	0.3	30	63
	4	Shielding & trailing line quality	8	0.3	30	72
	5	AVC fluctuation.	8	0.2	60	96

Continue............

Continue.............

Welding Process	1	Root Gap & Root Face	3	0.1	20	6
	2	Stretching of Shell	2	0.2	20	8
	3	Masking of Cu Shoe	5	0.2	10	10
	4	Torch Offcentre	6	0.1	20	12
	5	Mismatch	3	0.2	20	12
	6	Trailing Flow rate	3	0.5	10	15
	7	Purging Flow rate	4	0.5	10	20
	8	WEP angle & finishing	6	0.2	20	24
	9	WEP Cleaning	6	0.2	20	24
	10	Wire contact tip	4	0.2	40	32
	11	Protection of edges while grinding	4	0.3	30	36
	12	Arc Blow	6	0.1	60	36
	13	Change in current	4	0.5	20	40
	14	Change in voltage	4	0.5	20	40
	15	Manual Adjustment of Torch	4	0.5	20	40
	16	Burn Through	2	0.2	100	40
	17	Cleaning of shell from I/S and Outside	5	0.5	30	75
	18	Welder Skill	8	0.5	20	80
	19	Tack grinding quality	6	0.5	30	90
	20	Wire Cleaning	6	0.5	30	90
	21	WEP opening	5	0.5	50	125
	22	Change in wire feed	8	0.4	40	128
	23	Interpass grinding	7	0.6	40	168
	24	Wire Straightening	5	0.5	100	250
	25	Shielding Flow rate	8	0.8	50	320
	26	Scum Formation	9	0.9	90	729
NDT	1	Defect Depth issue	8	1	100	800

4) Improve Phase

The goals of this phase are to select problem solution, recognize the risks and implement selected solution. Practically, the improvement must investigate necessary knowledge based on brainstorming to create the best solution. The phase focuses on fully understanding the top causes identified in the Analyze phase, with the intent of either controlling or eliminating those causes to achieve breakthrough performance. This step use creative ways to find new ways to do things better, cheaper or faster. Improvisations in the process are done in order t o keep the variables within the specification limits.

5) Control Phase

The last phase of DMAIC is control, which is the phase in which we ensure that the processes continue 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 (irreversible product or process design changes). Controls are required to ensure that the improvements are maintained over time. The modified process is subjected to vigil at regular intervals of time to ensure that the key variables do not show any unacceptable variations.

IV CONCLUSION

Operational Six Sigma methodology was selected to solve the variation problem in a welding process. This Six Sigma improvement methodology, viz., DMAIC project shows that the performance of the company is increased to a better level as regards to: enhancement in customers' (both internal and external) satisfaction, adherence of delivery schedules, development of specific methods to redesign and reorganize a process with a view to reduce or eliminate errors, defects; development of more efficient, capable, reliable and consistent manufacturing process and more better overall process performance, creation of continuous improvement in productivity. The TIG welding process on MDN 250 material is analyzed and the expected failures are noted. From the analysis it is found that Lack of Fusion is the most risky defect in TIG welding with MDN 250 materials and improper shielding is also a serious issue while welding. The Root causes, effects and the preventive measures of all the possible failures are given along with the priorities. This analysis will be very much useful as a reference guide of TIG welding MDN 250 material failures. The integrated approach of RCA with FMEA serves as a better way to maintain the work piece defect free.

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