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Improving TIG Welding Quality using DMAIC

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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 and maintains consistent quality of the process output.***

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

1. 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.

2. Maraging Steel

Maraging steel are iron-nickel alloys designed to combine high strength with good fracture toughness the properties are achieved through the age hardening 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].

3. DMAIC Methodology

The Six Sigma concept was introduced in the early 80's by Motorola due to two reasons. First reason was the nature of mass production and second reason was the threat of the Japanese products in the American market. The implementation of Six Sigma is always done using DMAIC approach. In some of the above mentioned references, the five letters abbreviations are simply 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?

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. 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].

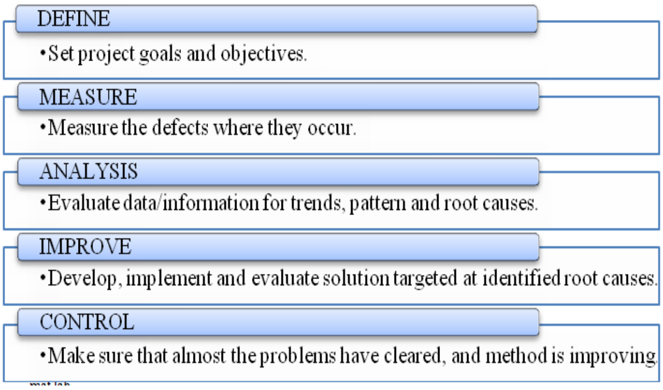

Figure 1: Roadmap to Six Sigma

3.1 Define Phase

In this phase, define the purpose of project, 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 Dhatu Ltd.	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	Defect free weld	Machine shop

3.2 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.

3.3 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.

3.3.1 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.2

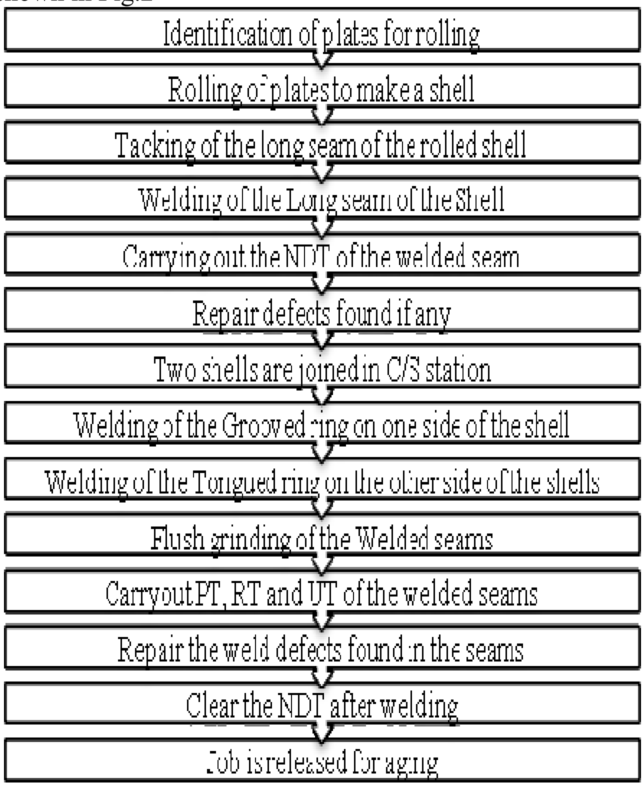

Figure 2: Activity Flow Chart

3.3.2 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.

Table 2 : Cause Effect Matrix

Category	Sr. No.	Cause(X)	Severity	occurrenc	Detection	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
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 Off centre	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

Continue…

	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

3.4 Improve Phase

The Improve phase is the fourth step in DMAIC improvement cycle and its aim is to find and implement measures that would solve the problem. 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 to keep the variables within the specification limits. Actions identified for identified causes shown in Table 3.

Table 3: Action Plan for Identified Causes

Sr. No.	*Category*	*Cause(X)*	*Actions*
1	NDT	Defect Interpretation issue	Trials to be conducted with D7 film and machine with less than 2mm focal spot
2	Welding Process	Scum Formation	Die checker to use Lint free clothes only for cleaning. Proper training to be given to die-checker for interpass cleaning post PT
3	Welding Process	Shielding Flow rate	Flow rate to be reduced from 30lpm to 20lpm and trials to be taken.

Continue…

Sr. No.	*Category*	*CAUSE(X)*	*Actions*
4	Welding Process	Tungsten Electrode preparation	Wire cut template for angle check to be implemented. Tungsten Grinding to be axial in direction only. Sampling inspection to be done
5	Welding Process	Filler Wire issue	Wire straightening to be done in case of deviation. PMG to take the cast and helix issue with customer.
6	Welding Boom Related	Method of cleaning of Developer.	Die checker to use Lint free clothes only for cleaning. Proper training to be given to die-checker for interpass cleaning post PT
7	Welding Process	Interpass grinding	Operator level training to be provided. Interpass PT to be done.
8	Welding Station	Cleanlines s	Additional Manpower Deployed
9	Accessorie s for Setup and Welding	Cu-Shoes Cleaning and leakage Check.	All existing Cu shoes and connectors to be thoroughly inspected and cleaned
10	Welding Process	Change in wire feed	Password protection implemented.
11	Welding Station	Jerking	To be taken up with maintenance/production dept.
12	Welding Process	WEP opening	Measurement after root pass and maintain minimum opening of 10mm by manual grinding.
13	Accessorie s for Setup and Welding	White cloth for cleaning.	Co-ordinate with Stores for Supply of Lint free cloth
14	Welding Boom Related	AVC fluctuation.	To be discussed with Maintenance and PM plan to be decided.
15	Welding Boom Related	Shielding and trailing line quality.	New Pipes to be installed in Station and checked.

3.5 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.

4. Results And Discussions

Six Sigma is an effective way to find out where the greatest process needs array and which the softest points of the process array. Also, Six Sigma provide measurable indicators and adequate data for analytical analysis. Systematic application of Six Sigma DMAIC tools and methodology within production results with several achievements the achieved results after implementation:

a) Reduced possibility of failure.
b) Reduced costs of poor quality (CORQ).
c) Reduced labours expenses.
d) Improved customer satisfaction.

Defect ratio after six sigma implementation calculated as 0.5 % from Table 7.1 This Defect ratio is transformed to Sigma level as follows:

Yield = 100- Deffective ratio = 100 - 0.5 = 99.5%

Sigma level after implementation $=\varphi^{-1}(0.995) + 1.5 = 3.5$

The results indicated that, for the year of 2012-13 the calculated Defect ratio 1.1% and yield was 98.9%, from this yield, the sigma level was calculated and found to be 2.98. Using the company's target of 0.4% defect ratio, the target sigma level was calculated to be 3.7 and as per design yield of 99.6% as mentioned earlier. After applying Six Sigma methodology the yield after the improvement efforts reached 99.5% corresponding to a sigma level of 3.5

5. Conclusion

Operational Six Sigma methodology was selected to solve the variation problem in a welding process. The study proposal a real time monitoring system by which the weld defects can be eliminated, without destructive resting. Due to 100% inspection, error made by the selective sampling can be eliminated, reducing the scrap page cost. The implementation of the new system will pay for itself in a long run. 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 and "do it right the first time" mindset. Six Sigma provides business leaders and executives with the strategy, methods, tools and techniques to change their organizations. Six Sigma as a powerful business strategy has been well recognized as an imperative for achieving and sustaining operational (process) effectiveness, producing significant savings to the bottom line and thereby achieving organizational excellence. If implemented properly with total commitment and focus, Six Sigma can put industries at the forefront of the global competition.

6. Future Scope

Further research is possible in the direction of what the people and organization has to sacrifice for getting this breakthrough in their process. As no gains possible without companying improvement in work habit Six Sigma is continues improvement process involving all operations in the work place and more such opportunities are potentially available in the workplace.

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