An Implementation Of Six-Sigma In Steel Tube Welding: A Case Study

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Abstract
In this paper we have tried to maintain a balance mix of surveys as well as experimental observation to provide a clear concept of a steel tube welding by using DMAIC (Define, Measure, Analysis, Improve and Control) technology under Six-Sigma in order to reduce leakage problem in steel tube welding. By taking various tube welding parameter in a machining process the tube welding strength (yield stress and tensile stress) increased. By taking into consideration and analyzing the drawbacks in the previous researches in context with constraints like finishing, quality, mechanical properties, time taken for welding and selection of material, we implemented our own welding method which has the ability to withstand the all these features and can easily rectify the leakage problems arising in the machining operations.

Keywords: Six Sigma, DMAIC, tube welding, yield stress, tensile stress.

1. Introduction
Six-Sigma is a problem solving methodology that reduce cost and improvement customer satisfaction and greatly reduce waste in all the process involved creation and delivery of the product and service. Six-Sigma process involves collection of data, measurement and statistics to find out the different types of factors and parameter. Six-Sigma has been a powerful and successful tool in manufacturing industries to reduce rate of rejects and to enhance productivity. The service industries are diversified and the features are different from manufacturing industries. Thus, the use of Six-Sigma in service industries and its benefits are limited to some specific types of services like health care and banks. Quality management has been an important management strategy for achieving competitive advantages and improvements. Traditional quality concepts like Statistical Quality Control, Statistical Process Control, Zero Defects and Total Quality Management, have been key players for many years; While Six-Sigma is a more recent initiative quality improvement to gain popularity and acceptance in many industries across the world (Hendry and Nonthaleerak, 2005). The basic elements of Six-Sigma like, Statistical Process Control, Failure Mode Effect Analysis, Gage Repeatability and Reproducibility and other tools that have been on reduction of rejects and enhancing the quality. Six-Sigma provides a framework in which all these tools can be performed with management support.

Apply the Six-Sigma technique on the steel tube welding process for the solved leakage problem in steel tube used by electric resistance welding low voltage, high current process. Electric Resistance Welding (ERW) Tube manufactured by continuous roll forming and hot coil material into a tube shape butt welding the weld seam after heating/melting the coil edge using the heat generate by passing a high frequency current through the edge at the seam of the electric resistance welding butt welding and welding beads on the tube inside and outside surface are removed. Full length grinding follow by seam heat treatment to improve the weld microstructure after electric resistance welding line tubes are cut to the specified length and tubes are passed for quality assurance process and check quality and leakage defect and tube strength, tubes dimension through the tube testing process. Through this manufacturing process to changes the parameter of tubes and reduced the tubes leakage problem. It can be shown in the figure

Fig. 1 Welded Tubing Manufacturing Process

2. Literature Review
The most resent quality philosophy to be adopted by business around the world is known as “Six-Sigma”. The founder of the “Six-Sigma” philosophy is Mike Harry (Harry and Schroeder 2000). Mike Harry developed and implemented his “Six-Sigma” philosophy with the Motorola Corporation and the philosophy has had great success at GE Corporation (Harry and Schroeder 2000). Many companies such as Ford, Xerox, Intel, Honda, Sony, Hitachi, Texas Instrument, American Express, etc have adopted the “Six-Sigma” quality philosophy. Ansari et al. has made an approach to implement a Six-Sigma Methodology to reduce errors, excessive cycle times, inefficient processes, and cost overruns related to financial reporting systems. A case study of Continuing Account Reconciliation Enhancement project was studied to streamline and standardize the establishment and...
The Six Sigma implementation resulted in a significant reduction in the average cycle time and cost, per unit of activity, needed to produce the required financial reports. The Six-Sigma DMAIC Methodology was used to streamline the ‘Continuing Account Reconciliation Enhancement’ process. The team followed the five phases of DMAIC in this project and the result was a significant reduction in errors, cycle times, and costs associated with preparing financial reports. The potential impact of cycle time reduction on both internal and external customer satisfaction was not measured in this study but could be incorporated into future. Bagaitkar has explained the results of Six Sigma movement at Tata Honeywell Ltd. The project undertaken was to reduce the travel costs per kilometer per month of the company. By the successful implementation of the Six Sigma methodology a remarkable improvement, month after month, had been noticed without a decrease in the total travelling kilometers per month. The process metric improvement had been reflected in gains in the business result metric. Oguz et al. has implemented Six-Sigma in the construction industry. Using a case study, a company is developing the Phase II of Jubail Industrial City in Saudi Arabia. The combination of Lean tools and Six-Sigma methodology is used on projects to improve the process by eliminating the variations and creating workflow in a process. Despite its relatively new introduction to the construction industry, it has been popularized by several organizations and adopted as the primary improvement process. The complexity of the construction project has its own unique and uncertain environments, which made the use of Lean Six Sigma methodology somehow different from the other industries, especially manufacturing. However, as seen on the case study, major Lean Six Sigma tools have been successfully applied to improve the process. The methodology of Lean Six sigma was effective in reducing variability of daily panel production rate. However, taking into account inherited uncertainty in construction processes, the value of Cp can be applied flexibly to construction processes. Rasis et al. have dealt with Paper Organizers International (POI) which offered a full range of filing, organizing and paper shuffling services. The purchasing department had noticed an increase in complaints from employees in the paper shuffling department about metallic securing devices breaking and failing to keep paper together. Define and measure phases of the Six Sigma methodology were used to define the problem using voice of the customer, Gauge R&R study and to calculate the DPMO level of the process. Henderson and Evan have reviewed the basic concepts of Six Sigma, its benefits, and successful approaches for implementation. They have concluded that keys for successful implementation include upper management support and involvement, organizational infrastructure, training, tools, and links to human resource based actions.

3. Methodology

**DMAIC** (Define, Measure, Analysis, Improve, Control) method was implemented. It is as explained below:

**Define**
Define the problem: Define phase is the first phase (critical phase) of the Six-Sigma that is the leader of the project and create map of steel tube welding process through the define phase create the high level view of process and understanding need of customer in this phase define the problem of steel tube welding (tube leakage) tube leakage problem show at the flow of fluid so creates leakage so these problem is the major problem of tubes.

**Measure**
Map out the current process: How does the process currently perform measurement is the critical throughout the life of the project in measure phase collect the steel tube welding data related to the welding parameter then measure the data and determine start point and base line of the process and create the planning. and the testing, refining steel tube welding and received more detailed welding perform process consider in the measure phase.

**Analysis**
Identify the cause of problem: In this phase analysis the steel tube welding data. This phase is the intertwined the measure phase and team select for the data set and team review at the data collection during the measure phase and they may be decide adjust the data collection plan and include additional information and continuously team analysis both data and process and time analysis, value analysis, map process analysis, after data collection these data display in the graph and chart for the visual indication for the problem in the process verify the root cause waste and defect in steel tube welding process.

**Improve**
Implement and verify the solution: In improve phase after data measure and data analysis and understanding problem then create idea for solve reduce steel tube leakage problem. Improve parameter changes related to the electric resistance welding

- improvement welding process technique
- welding material dimension
- welding speed
- weld material thickness
- in ERW used nitrogen gas

Above parameter changes to start electric resistance welding process and received data there data visual indicate on the graph and chart and received best result and then solved my leakage problem in steel tube welding.
Control
Maintain the solution: Control phase is a mini version of process management. Control phase is the last process in the DMAIC technique. In control phase check the market value of the product and launch product in the market and received customer. All process and technique apply on the steel tube welding then forward steel tube in control phase.

4. Result
In Steel Tube Welding product, solve leackage problem with Six-Sigma technology, used Electric Resistance Welding low voltage high current process and density of material 7.86 g/cm square then cooling system from water then used nitrogen gas for the reduced corrosion in steel welded tube and electrode angle 90 degree, changes the different parameter in tube welding process then increased the yield stress and tensile stress and testing of mechanical properties. Plot the graph by changing the parameter. When we are change the thickness (variable) then improve the welded tube strength show below in table and graph.

**Fig. 2: thickness v/s yield stress**
In this graph we are changes the thickness (vary) then variable slowly yield stress increase and strength of welded tube are increase so solve the leackage problem. In previous time steel tube strip thickness 1-2 mm thickness used in Gandhi Special Tube Ltd Halol (Gujrat) India. And maximum received strength (yield stress=275 Mpa, tensile stress=315 Mpa) but in my research work thickness increased to maximum strength(yield stress=350 Mpa, tensile stress=417 Mpa).

**Fig. 3: Thickness v/s Tensile Stress**
In this graph thickness vary to increased tensile stress and increased welded tube strength then reduced leakage problem through the Six–Sigma technique in my research work.

**Fig. 4: Nitrogen gas pressure v/s Yield Stress**
Nitrogen gas used for reduced corrosion in the steel tube through electric resistance welding process low voltage high current but nitrogen gas pressure effected on the steel tube strength then changes the increased nitrogen pressure and reduced yield stress show in fig: 3
Fig. 5: Nitrogen pressure v/s Tensile Stress
In this graph show the nitrogen gas pressure reduced then increased tensile stress so these improvement to automatically reduced leakage problem in steel tube welding at the flow of fluid in tube.

Fig. 6: Welding Speed v/s Yield Stress
In this graph changes the yield stress with welding speed, in electric resistance welding used low voltage high current. In ERW high speed strip converted into the tube so create defect because strip material shape perfectly no change in tube shape so at the testing time tube create leakage problem because material porosity problem from the high welding speed and reduced yield stress of welded tube, And reduced welding speed increased yield stress.

Fig. 7: Welding Speed v/s Tensile Stress
Show the graph, welding speed reduced then increased tensile stress and not created porosity at the ERW process, low voltage high current (2.4V, 15000 Amp.) strip converted in to the tube shape so automatically reduced leakage problem in welded tube.

3. Conclusion
From the present theoretical result of steel tube welding with Six-Sigma technique, and use of nitrogen gas and changes the welding pressure then increase strip thickness, and reduce welding speed to increased yield stress and tensile stress check the mechanical properties tube strength (yield stress and tensile stress) but maximum optimization result show in thickness v/s yield stress and tensile stress (yield=350 Mpa, tensile stress=417Mpa) in graph to solve the steel tube welding leakage problem at the flow of fluid in the steel tube, improve customer satisfaction.

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