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IMPLEMENTATION OF SIX SIGMA PROGRAM FOR LEAN MANUFACTURING TO REDUCE THE REWORK WASTE IN D.M MANUFACTURING UNIT BY ELIMINATING DEFECT OF LEAKAGE FROM S.S CONNECTION IN D.M UNIT OF INDUCTION MELTING FURNACE

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Abstract

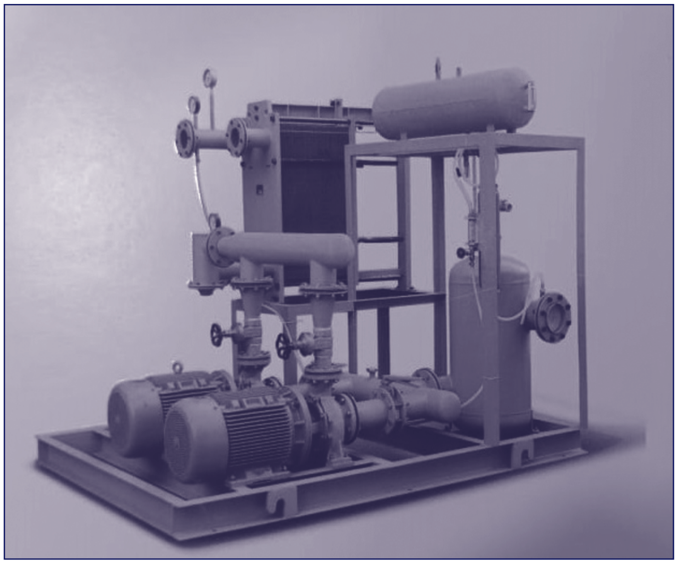
An induction furnace is an electrical furnace in which the heat is applied by induction heating of metal. Induction furnace capacities range from less than one kilogram to one hundred tons, and are used to melt iron and steel, copper and precious metals. Here DM Unit (Demineralized-water) is used for cooling of power devices and copper conductors. Conductivity of DM water is continuously monitored and power supply unit is tripped in case conductivity exceeds the set limit. Stainless steel sacrificial electrodes are used to prevent electrolysis of copper components. Magnet float assembly in conjunction with sensitive proximity switches are used to monitor the flow in different paths. The DM water cooling system with flow monitoring mechanism ensures enhanced life of water cooled copper conductor and power components. But major defects of the DM unit i.e. water leakage from S.S connections. It is a highly time consuming and expensive task to arrest the leakages once occurred at the shop floor or at the site. The location for this leakage has been in most cases from welding joints and connections. There have been many delays in commissioning lines due to these leakages and the resulting rework and have also caused complaints from site wherein the customer's plant hadinterruption of power during the period of rectification. We have selected this problem as a project and solve it by six sigma methodology to achieve first time right prevention of S.S Connection leakage which will eliminate production of defective parts and be a step towards Lean manufacturing in D.M Unit.

Keywords— Six Sigma, Leakage, S.S connection, Defect, Lean

INTRODUCTION

Subject project was undertaken at the DM manufacturing unit of Electrotherm India Limited, a reputed name in all segments of steel industry, foundries and heat treatment industry located at Ahmedabad Dist. Gujarat, Project selection has been based on the process defects and field performance data over a period of six months. Six sigma methodology is highly effective in eliminating the root cause of a problem and bringing a breakthrough change. Six sigma method has five phases namely DMAIC. On analysis of the data using the Pareto chart, it was found that one of the major area of concern was the leakages at the shop floor as well as at the site. To find the solution to this problem, the six sigma (DMAIC) methodology was used. A second level Pareto chart of process defects was prepared for this particular issue and various locations, components were found out. Using this information we moved to next phase of this methodology i.e. Measure, where using various tools such as Process Mapping, Cause and Effect Diagram (CED) and FMEA (Failure Mode Effect and Analysis) the probable reasons of the problem were identified. The probable reasons identified through FMEA were then funneled using various tools of Analyze Phase such as Capability Analysis to get the critical reasons. These reasons were then worked on in Improve Phase and by continuously monitoring result when we got the solution i.e. the arrangement which would ensure first time right performance for leakages and remove waste of rework to arrest the leakages and stoppages of production, allowing the lean manufacturing approach in DM manufacturing unit. Finally, a control plan was evolved to ensure sustenance of the solution in future.

Fig- 1.1



LITERATURE REVIEW

Six Sigma has been the subject of interest to many researchers over the years. Many researchers have studied Six Sigma programs and identified many critical dimensions of six sigma programs. For example, Brue Greg; "Six Sigma for Managers, McAdam and Evans (2004) [2] for Challenge to Six Sigma in a high technology mass-manufacturing of transformers, Savolainen and Haikonen (2007) [3] for dynamics of organizational learning and continuous improvement in Six Sigma implementation. research of Antony and Banuelas (2002)[4] Key ingredients for the effective implementation of Six Sigma program., Coronado and Antony (2002)[5] for Critical success factors for the successful implementation of Six Sigma projects in organizations , Gitlow and Levine, 2005[6] for Six Sigma for Green Belts and Champions: Foundations, DMAIC, Tools, Cases, Keller (2005) [7] points out, Six Sigma programs have performance metrics and measurements based on cost, quality, and schedules ,Davison and Al-Shaghana (2007)[8] for the link between Six Sigma and quality culture—an empirical study, Minitab software [9] for various statistical tools [10] ong, Chen Kwang, "Six Sigma–DMAIC Approach for Improving Induction Furnace Efficiency and Output at an Iron Foundry Plant"(2016).https://repository.stcloudstate.edu/mme_etds/53.

CASE STUDY

This case study is undertaken at one of the leading DM manufacturing Unit Company named ELECTROTHERM INDIA LTD in India. The unit produces DM ranging from 5 Ton to 50 ton Manufacturing Unit is an engineering industry with lot of assembly operations categorized in various sections such as Power supply unit, heat exchangers, S.S connections, motor & Pump-assembly & S.S tank assembly. Our area of work is in the solid state power supply unit of DM manufacturing. The company had a challenge to produce the DM Unit free from leakages at the shop floor and as well as at the site. Any leakage whether at the shop floor or at site would pose lot of rework and interruption to the production process or to the user. For our point of view, the target of first timer right is not achieved due to such defects and the concept of Lean manufacturing to DM Unit cannot be applied. The company is also increasing its global footprint and needs to be cost competitive to lead the market. The increased application of Lean manufacturing can definitely help the company towards its goal.

DATA COLLECTION

Data is the backbone of all Six Sigma projects. We employed this concept in our study. Data of qualitative nature was collected through various documents available in form of minutes of meeting, letters, e mails, reports and studies etc. Quantitative data were collected in the form of customer complaint reports, manufacturing plans and schedules, archival records of financial data, quality performance reports, purchase orders, operational data (such as category of products produced), performance measurements (such as annual sales and responsiveness). Additional qualitative data were collected through interactions and open information exchange sessions with various interested parties such as managers, engineers, technicians and other employees. The free and fairness of our sessions enabled the capturing of the micro level details of the process and product issues related to our project. Further qualitative data were collected by observation and taking the data based decisions during the implementation. Also qualitative data were collected for the components, vendor source, process parameters, detection results, long rework hours, wastage of material, time etc. These indicated the need for further study of the process to reach to the vital few X's affecting the Y of our project that is the issue of water leakages from S.S connections. During the study the researcher kept a research log that documented each problem encountered during the implementation, in addition to the thoughts and insights gained during the process. We have included S.S 304 type (where nominal composition of type 304 being **18% chromium and 8% nickel)** in our study. Data collected is in Metric units i.e. ppm (parts per million) with Base ppm of our case as 187500 (DPMO) and target as 12500 (DPMO) ppm after completion of the project.

DATA ANALYSIS

The researchers with their experience on the Six Sigma methodology maintained the rig our throughout the progress of their study. The preliminary data analysis in case study is the reflection by the researcher on their own experience. The researchers identified common threads by grouping and analyzing the experiences of themselves and other contributing participants. Data analysis however was the base for identifying probable root causes and prioritizing alternative solutions. In spirit, data analyses is the collection of all the relevant data in variable or attribute form, applying analysis tools and deriving meaningful information for decision making. In this study, the unit of analysis was the operational/department level where the data was generated. To understand the process and examine the flow of information through the system; we employed process mapping. Each activity in the manufacturing process is represented on a two-dimensional scale. The process steps are then connected with arrows showing the direction of service flows. These maps helped identify where process stoppages occurred, major rework areas, decision/inspection points, defect levels at intermediate stages.

The researchers maintained the flavor of six sigma methodology on daily basis. They spent several hours on sharing the study objective methodology with the interested parties. They worked based on the project Gantt chart and kept a close eye on the target completion of stages and milestones. All the information gathered from the experience of the experts and operational level personnel were verified against the data and only data supported ideas were taken further for implementation. Results of the ideas implemented during the current day were reviewed for performance. The results were taken through the further steps of six sigma methodology to reach the goal. The production process progressed in steps and the researchers were involved throughout the steps to capture the significant results and conclusions. Refer Process Map showing typical process mapping for production of process.

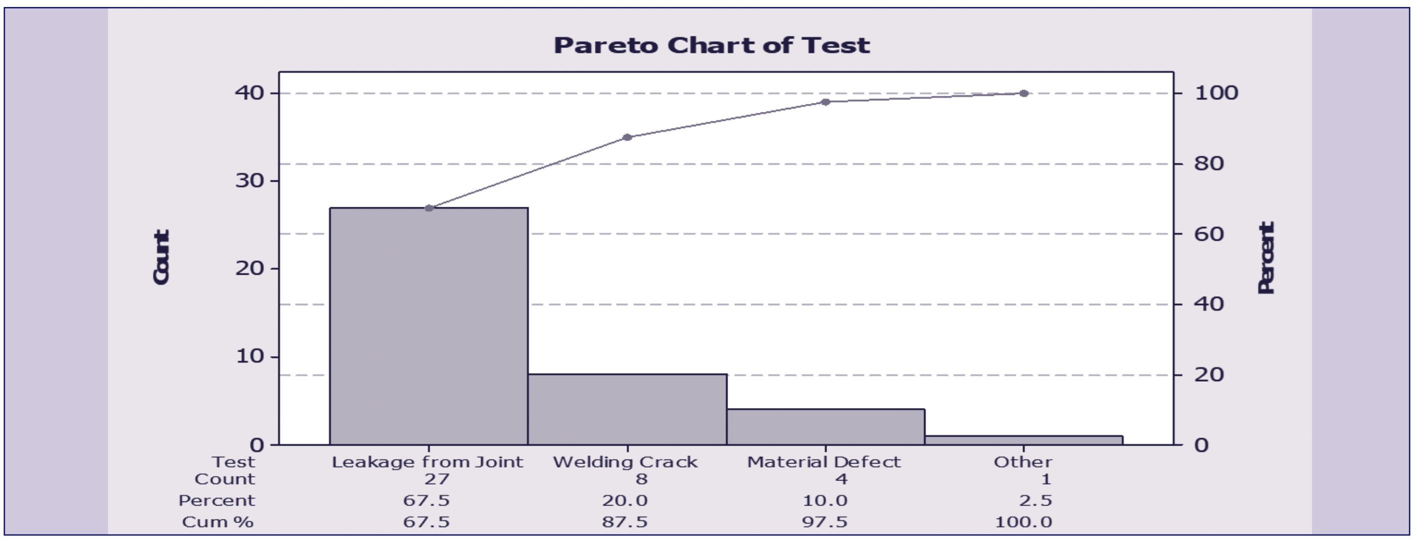
IMPLEMENTATION OF SIX SIGMA METHODOLOGY

Our project is based on six sigma methodology which is often called as DMAIC process. This is advanced breakthrough method of identifying and resolving issues permanently and taking the processes to the next level. The improvements are not incremental in nature but are massive taking the performance levels to exponential rise. There are five phases of solving problem by DMAIC methodology as name suggests: Define phase, Measure Phase, Analysis Phase, Improve phase & control phase. We will discuss each phase in relevance to our project progress

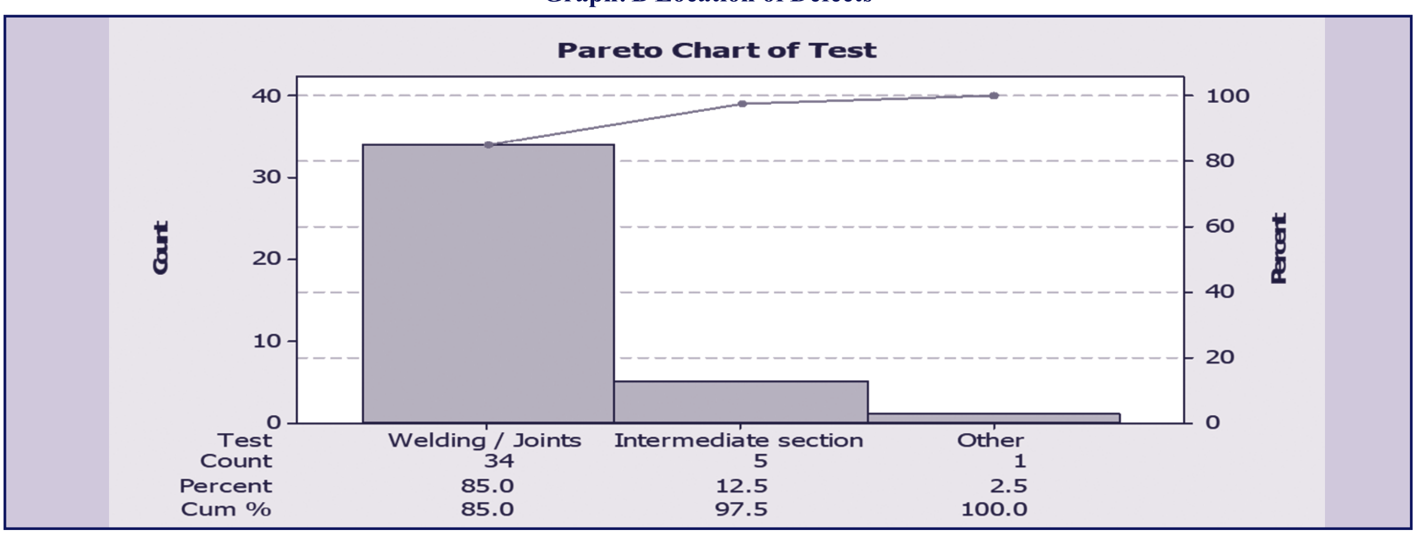
DEFINE PHASE

In this phase we define problem in measurable form i.e. Leakages in DM manufactured with base data 187500 (DPMO) ppm and target ppm 12500 (DPMO) after completing the project. For defining the problem we have collected data form customer complaints, MOM, our and vendor in-process checks etc. as mentioned in Data collection method. We prepared Pareto charts using Minitab software to define our problem. As mentioned in Graphs: A & B below

Graph: A Process Defects



Graph: B Location of Defects



MEASURE PHASE

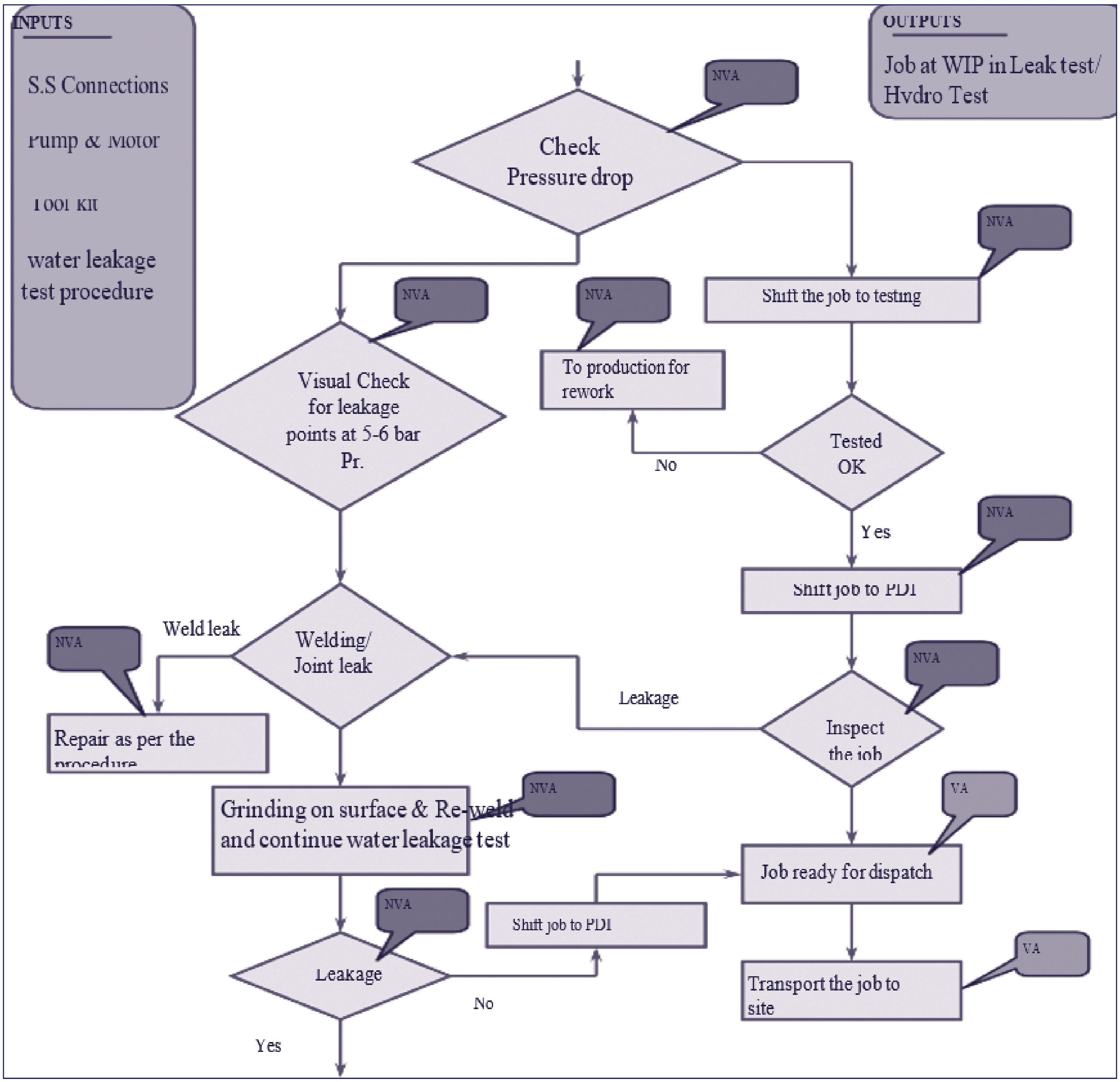
Under Measure phase, we establish the base levels of the probable many X's contributing to the problem at the place of project. It is based on mathematical equation $Y=f(X)$. It means 'Y' is the function of 'X'. i.e., Y is the desired result or may be the undesired result or problem as we see in our study in form of leakage and is dependent on various X's means causes for leakage at various stages of the product.

The causes or X's were gathered from the inputs of cross functional team. In our case study, team members form production, quality, material department heads, executives and technicians, under guidance of Guide.

Thereafter we used various six sigma tools to find the vital few causes as follows:

Process Map: A process map is graphic representation of a process, showing the sequence of tasks using a modified version of standard flow charting symbols. The map of a work process is a picture of how people do their work .Work process maps are similar to road maps in that there are many alternative routes that will accomplish the objective. In any given circumstance, one route may be better than others. By creating a process map, the various alternatives are displayed and effective planning [*to improve the process*] is facilitated. Refer Process Map which shows typical process mapping of S.S Connection fabrication & assembly for production of DM Unit.

Process Map



Cause & Effect Diagram*:* The Cause & Effect Diagram (CED), also sometimes called the 'fishbone' diagram, is a tool for discovering all the possible causes for a particular effect. The major purpose of the CE Diagram is to act as a first step in problem solving by generating a comprehensive list of possible causes. It can lead to immediate identification of major causes and point to the potential remedial actions or, failing this, it may indicate the best potential areas for further exploration and analysis. CE Diagrams are also often called Ishikawa Diagrams, after their inventor. By a brainstorming session various causes were gathered and placed into the relevant branch. Refer Graph D.

Graph D C&E for Water Leakages from S.S Connection

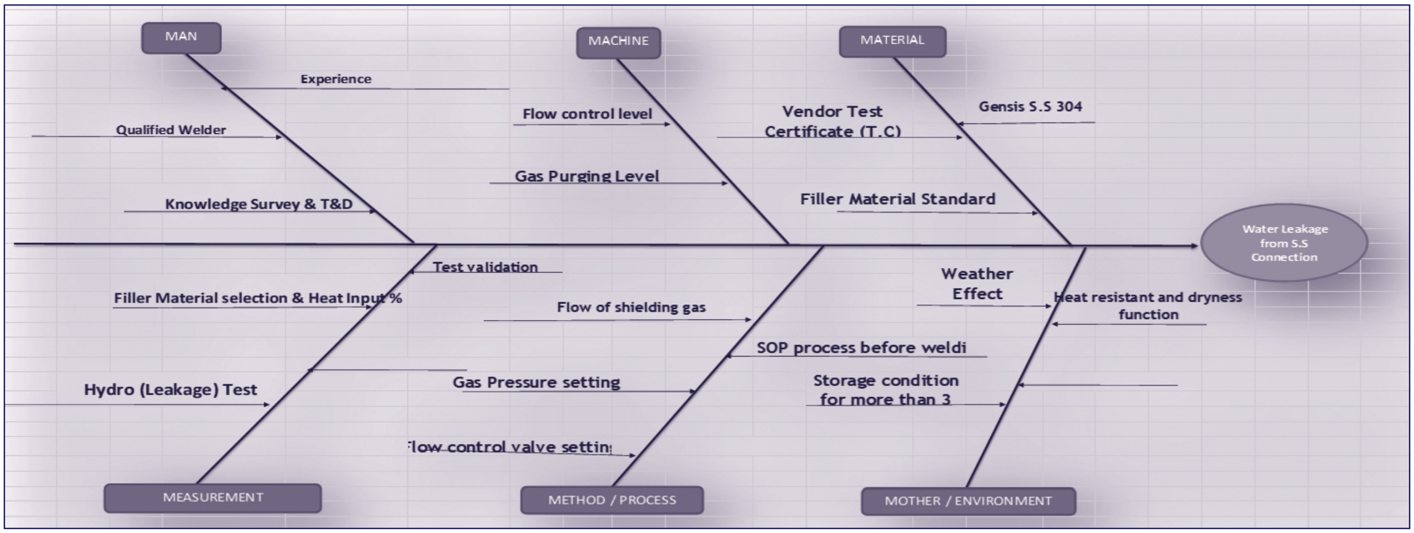
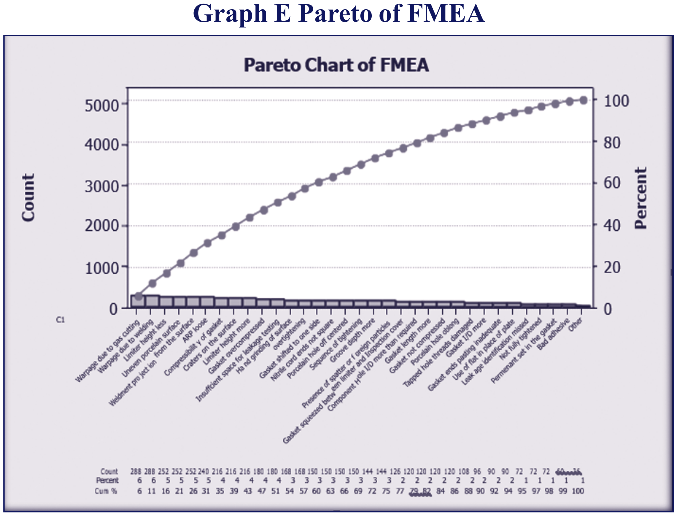


Table 1

Before FMEA							Yellow highlighted cells will update automa		
Sr.No.	Item and Function	Potential Failure Mode	Potential Effect(s) of Failure	SEV	Potential Cause(s)/Mechanism(s) of Failure	OCC	Current Design Controls	DET	RPN
1	DM Unit	Leakage from S.S Connection	Reduce the customers satisfaction and confidence	9	Too Much Heat Input duringwelding process	3	Heat Input during process is defined at Vendor end	2	54
			stop the production and production loss	9	Water Quality- High PH value water thus results in corrosion	7	Use TAP water for Hydro Test	6	378
			plant is under maintenance	9	Filler Material selection wrong	8	Use regular selectied electrode for SS 304	7	504
			Product replacement/Order loss	9	poor Quality of welding at Vendor end	5	No Welder training & No welder certified	2	90

Graph E Pareto of FMEA

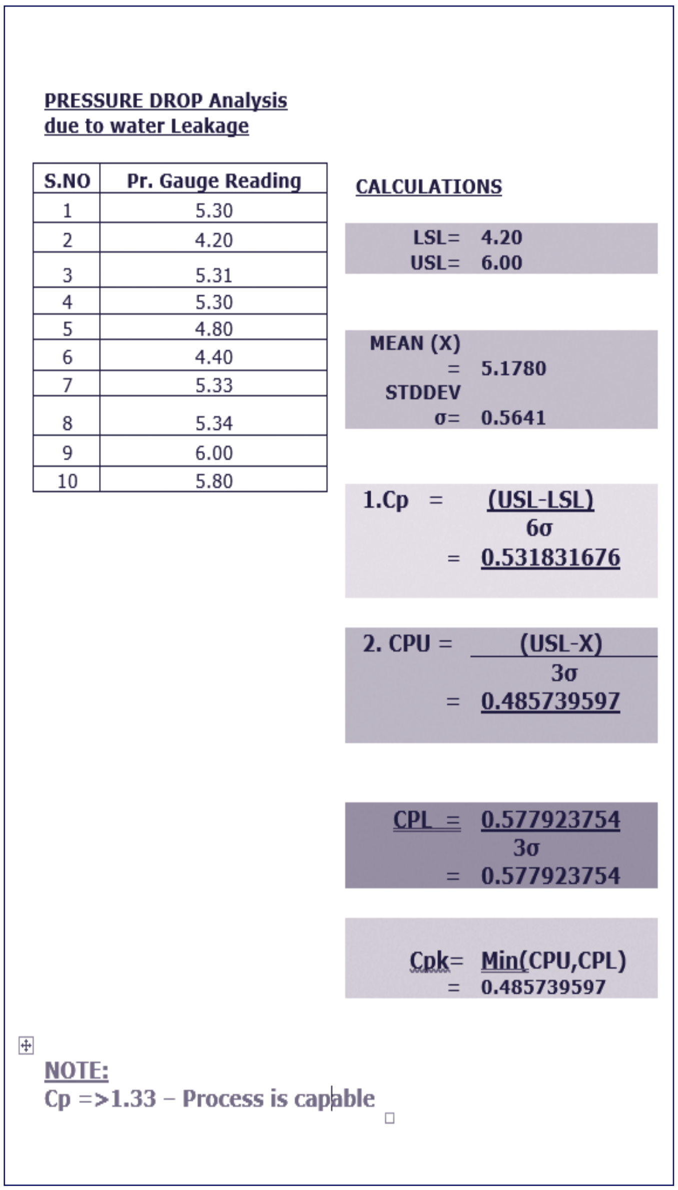


ANALYZE PHASE

This is the phase of six sigma methodology where using various tools the X's obtained from the Measure Phase are reduced to vital few which then can be taken up for improvement. The effectiveness of this phase is very critical for carrying out the improvement experiments and the feasibility of such experiments. Therefore lot of time was spent on analysis activities in this phase to filter out the trivial many X's from the probable X's.

Capability Analysis: Capability analysis is a set of calculations used to assess whether a system is statistically able to meet a set of specifications or requirements. To complete the calculations, a set of data is required, usually generated by a control chart; however, data can be collected specifically for this purpose. Specifications or requirements are the numerical values within which the system is expected to operate, that is, the minimum and maximum acceptable values. Occasionally there is only one limit, a maximum or minimum. Customers, engineers, or managers usually set specifications. Specifications are numerical requirements, goals, aims, or standards. It is important to remember that specifications are not the same as control limits. Control limits come from control charts and are based on the data. Specifications are the numerical requirements of the system. Capability analysis is summarized in indices; these indices show a system's ability to meet its numerical requirements. They can be monitored and reported over time to show how a system is changing. Various capability indices are presented in this section; however, the main indices used are Cp and Cpk. The indices are easy to interpret; for example, a Cpk of more than one indicates that the system is producing within the specifications or requirements. If the Cpk is less than one, the system is producing data outside the specifications or requirements. This section contains detailed explanations of various capability indices and their interpretation.

PROCESS FLOW FOR PROCESS CAPABILITY



PRESSURE DROP Analysis due to water Leakage

S.NO	Pr. Gauge Reading
1	5.30
2	4.20
3	5.31
4	5.30
5	4.80
6	4.40
7	5.33
8	5.34
9	6.00
10	5.80

CALCULATIONS

LSL= 4.20
USL= 6.00

MEAN (X) = 5.1780
STDDEV σ= 0.5641

1.Cp = (USL-LSL) / 6σ = 0.531831676

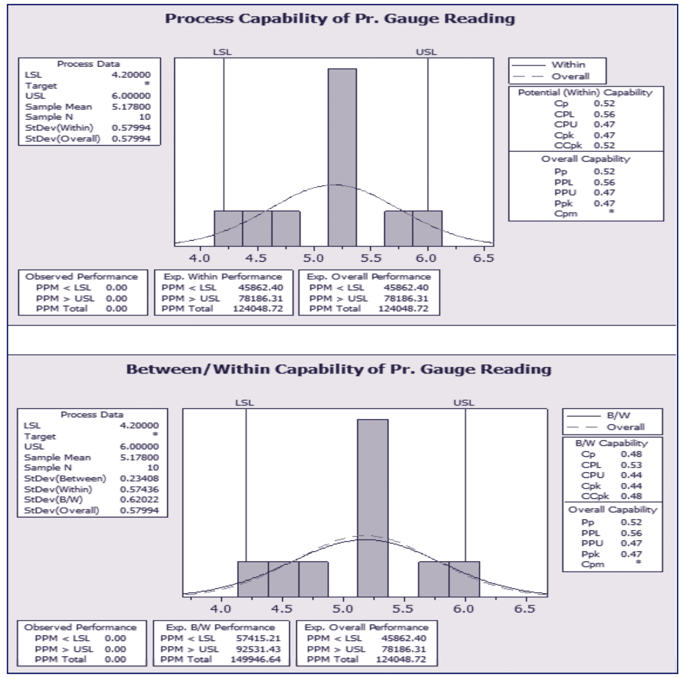
2. CPU = (USL-X) / 3σ = 0.485739597

CPL = 0.577923754 / 3σ = 0.577923754

Cpk= Min(CPU,CPL) = 0.485739597

NOTE:
Cp =>1.33 – Process is capable

Graph F Capability Analysis of Pressure Reading

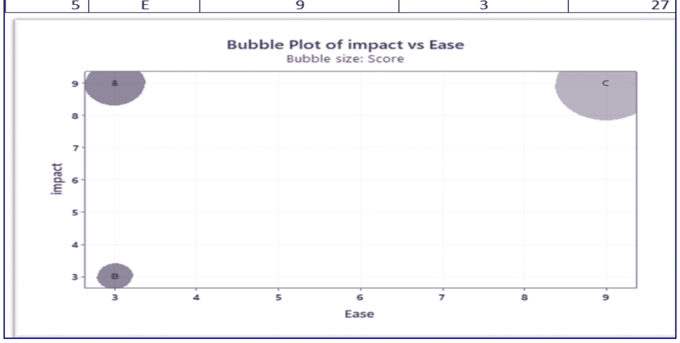


IMPROVE PHASE

With the preceding effective work in the Measure and Analyze phase the number of X's in the Improve phase is limited and this phase can be completed in quick time. The objective of Improve Phase is to carry out the experiments to identify improvement breakthroughs, to improve the capability of the X's and finding the right levels, attempting to make the X's redundant, select preferred approach, determine the new Sigma level, design dashboards/ scorecards, finalizing the improved process and giving a complete solution. In our project we worked on improving the vital X's and found an alternate of Stainless Steel plate to make all the X's related to welding redundant. All of these would have required huge effort to maintain the improved levels taking into account the manual involvement at various vendors, designs. We also introduced the process of machining the surface of porcelain parts of bushings and found that the bushings thus mounted on the tanks were free from leakages thus meeting our DOE criteria and the process became first time right providing the way towards going Lean.

Solution Prioritization

Sr.No.	Solution	Impact (1, 3, 9)	Ease (1, 3, 9)	Score
1	A	9	3	27
2	B	3	3	9
3	C	9	9	81
4	D	3	3	9
5	E	9	3	27



BEFORE

Opportunities for defect per unit	2
Defects	15
Sample Size	40
DPO	0.1875
DPMO	187500
Sigma Level	2.39

AFTER IMPROVEMENTS - TARGET

Opportunities for defect per unit	2
Defects	1
Sample Size	40
DPO	0.0125
DPMO	12500
Sigma Level	3.74

CONTROL PHASE

The control phase as mentioned earlier is very important for the sustenance of the improvements recommended and gives permanence to the solutions discovered. This also completes the handover of the project to the regular process owners who would implement the solutions and ripe the benefits, reconfirm the effectiveness of the project undertaken and establish credibility of the company's Six Sigma program. The design specifications for the S.S 304 material and Filler Material are changed based on the recommendations of this project to ensure continued implementation for future.

CONCLUSION

The motive of this research was establishing connect between Lean manufacturing and Six Sigma, the two powerful pillars of the modern industrial revolution. The major hurdle in achieving a flawless production cycle is the presence of defects in the processes being carried out, defects in the inputs to the process in form of material, components, information, sub-assemblies. The research identifies Six Sigma methodology as a strong enabler of Lean Manufacturing. Using a successful Six Sigma program in a Transformer manufacturing unit this research developed an implementation model consisting of the DMAIC rigour. The steps of DMA enable establishing the problem in measurable form, finding out the existing current levels of the result as well as contributing inputs or causes and all this in real time. The strong data based approach ensures the objectivity of the whole process and eliminates the traditional mistakes of experience based or gut feeling based decision making. The steps of IC are then carried out with concentrated limited effort to find exhaustive solutions using different level of the X's and providing the breakthrough for taking the process to the level of virtual zero defects. In addition, important for both practitioners and academicians, several areas of future research are also discussed regarding the implementation model. Lastly, this research provides a framework, to use the six sigma methodology for effectively guiding the journey towards Lean manufacturing. Implementation of Six Sigma programs to reduce variation or waste from the operations. It provides the newer view for organizations to decide the direction or objective of their Six Sigma programs. More research in this area is necessary to contribute to the science and practice of implementation of Six Sigma or any other process improvement model, to reduce waste and create value. The solutions recommended in this case study support radical thinking, de-bottlenecking and eliminating defects making the process smooth and supportive for Lean.

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