Improving Quality and Productivity in Switchgear Tank Welding through Poka-Yoke and Waste Elimination in Robotic Welding Shop

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Abstract - *Now a days manufacturing industries are facing a greater competition in the market. Because of this, they try to improve and increase both quality and productivity continuously. One way to increase the productivity is to increase the availability of existing machines; Total productive maintenance aims to increase the availability of existing equipment so no further capital investment is needed. Availability of machines can be increased by reducing the downtime or Breakdowns of the machines. The main objective of this study is to find out the major breakdowns causing production losses to the company and to suggest counter measures by which these problems can be reduced. Root cause analysis is conducted to find the root cause of breakdowns and some parallel improvement opportunities were also identified for implementation so as to reduce the downtime.*

Key Words: Switchgear, Welding, Fixture, Poka-Yoke, Pareto Chart, ISMC Channel.

1. INTRODUCTION

Productivity improvement is one of the core strategies towards manufacturing excellence and it is also necessary to achieve good financial and operational performance. It enhances customer satisfaction and reduce time and cost to develop, produce and deliver products and service. Productivity has a positive and significant relationship to performance measurement for process utilization, process output, product costs, and work-in-process inventory levels and on-time delivery. Improvement can be in the form of elimination, correction (repair) of ineffective processing, simplifying the process, optimizing the system, reducing variation.

Minimizing the number of defects is important to any company since it influence their outputs and profits. The aim of this paper is to study the implementation of industrial engineering tools in a manufacturing of Switch Gear part (tank) weighing about 100 kilogram. This study starts with reading the standard operation procedures and analysing the process flow to get the whole idea on how to manufacture tank of switch gear. At the same time, observations at the production line were made to identify problem occurs in the production line. By using check sheet, the defect data from each station were collected and have been analysed using Pareto Chart. From the chart, it is found that robotic welding workstation shows the highest number of defects. Based on observation at the welding workstation, the existing method used to weld the tank was inappropriate because the operator need to take new reference point for new tank. Then, by using cause and effect diagram, the root cause of the problem was identified and solutions to overcome the problem were proposed.

1.1 Problem Statement

Previously, operation are performed as follows:

1. Loading of tank manually on welding workstation
2. Handling of tank done manually
3. Various operations like spot welding, stud welding, tank handling, cleaning and inspection are performed manually.
4. Welding problems like spatters, thermal patches add the cost of cleaning. These increases the time required for manufacturing.

1.2 Objective

- Increase Productivity of Welding Shop.
- Reduce Non Valued Activities.
    - ➢ Handling of Switchgear Tank
    - ➢ Cleaning of Tank
    - ➢ Reduce Spatters during Stud Welding
- Reduce Warp edge of Sheet.
- Reduce effect of Thermal Stresses.
- Improve Quality of Product.

A fixture need to be designed in order to fulfil all objectives.

1.3 Scope

Scope of above project is as follows:

1. By implementation of different Quality tools, Quality and productivity of product can be increased.

2. Also, these Quality tools can be used to increase efficiency and effectiveness of production.
3. Designing of fixture and Templates reduces the Workmanship.
4. Automation of designed fixture and its integration with PLC and SCADA system is possible.

1.4 Methodology

A productivity improvement technique is the methodology chosen to carry out to increase the production of switchgear tank manufacturing. A framework of the work to be carried is given as follows:

- Analyse Manufacturing Processes Associated With Given Workstation.
- Identify the problems at workstation.
- Identifying Possible NVA(Non Value Added Activities)
- Prioritization Using Pareto Analysis.
- Design of holding Fixture & Templates.
- Solving problems by using following Quality Management Tools:
  - Root Cause Analysis , Pareto Charts
  - Poka Yoke
  - FMEA, DMAIC

2. SWITCHGEAR

In an electric power system, switchgear is the combination of electrical disconnect switches, fuses or circuit breakers used to control, protect and isolate electrical equipment. Switchgear is used both to de-energize equipment to allow work to be done and to clear faults downstream. This type of equipment is directly linked to the reliability of the electricity supply.

Fig 2.1: Switchgear

2.1 Functions

One of the basic functions of switchgear is protection, which is interruption of short-circuit and overload fault currents while maintaining service to unaffected circuits. Switchgear also provides isolation of circuits from power supplies. Switchgear is also used to enhance system availability by allowing more than one source to feed a load.

2.2 Productivity

The term productivity can be used to examine efficiency and effectiveness of any activity conducted in an economy, business, government or by individuals. For example, learning or studying methods used by students that include reading and/or writing the content of a topic and revising the topic by saying out aloud or rewriting. Efficiency, effectiveness and productivity can also be evaluated for businesses in service sector. Productivity however, is broadly evaluated mostly through service volume, delivery processes and customer-perceived quality in services offered. In the context of the real world, productivity is mostly examined and evaluated with reference to businesses or an economy. Accordingly, it is essential to study productivity in order to:-

- Understand the processes of a business
- Control the business processes
- Continuously improve processes
- Assess performance of a business
- Determine a business ability to sustain in the long run

In order to increase productivity, Monitor how much time you spend on tasks, and prioritize important work. Productivity can be reduced if you allocate time inefficiently. Use programs such as Rescue Time to increase productivity by tracking the time you spend on specific applications.

2.3 Quality

It is also defined as fitness for purpose. Quality is a perceptual, conditional, and somewhat subjective attribute and may be understood differently by different people. Consumers may focus on the specification quality of a product/service, or how it compares to competitors in the marketplace. Producers might measure the conformance quality, or degree to which the product/service was produced correctly.

Support personnel may measure quality in the degree that a product is reliable, maintainable, or sustainable. A quality item (an item that has quality) has the ability to perform satisfactorily in service and is suitable for its intended purpose.

2.4 Poka Yoke

Poka-yoke is a Japanese term that means "mistake-proofing" or “inadvertent error prevention”. The key word in the second translation, often omitted, is "inadvertent". There is no Poka Yoke solution that protects against an operator’s sabotage, but sabotage is a rare behaviour among people. A poka-yoke is any mechanism in a lean manufacturing process that helps an equipment operator avoid (yokeru) mistakes (poka). Its purpose is to eliminate product defects by preventing, correcting, or drawing attention to human errors as they occur. The concept was formalised, and the term adopted, by Shigeo Shingo as part of the Toyota Production System. It was originally described as baka-yoke, but as this means "fool-proofing" (or "idiot-proofing") the name was changed to the milder poka-yoke.

2.4.1 History

The term poka-yoke was applied by Shigeo Shingo in the 1960s to industrial processes designed to prevent human errors.[5] Shingo redesigned a process in which factory workers, while assembling a small switch, would often forget to insert the required spring under one of the switch buttons. In the redesigned process, the worker would perform the task in two steps, first preparing the two required springs and placing them in a placeholder, then inserting the springs from the placeholder into the switch. When a spring remained in the placeholder, the workers knew that they had forgotten to insert it and could correct the mistake effortlessly.

Shingo distinguished between the concepts of inevitable human mistakes and defects in the production. Defects occur when the mistakes are allowed to reach the customer. The aim of poka-yoke is to design the process so that mistakes can be detected and corrected immediately, eliminating defects at the source.

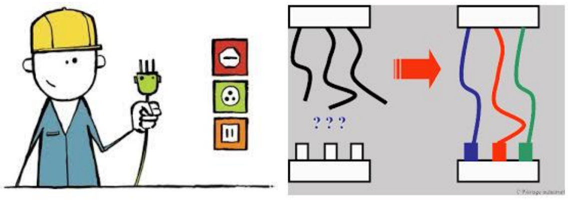


Fig 2.2: Application of Poka Yoke

2.4.2 Implementation of Poka Yoke

Shigeo Shingo recognized three types of poka-yoke for detecting and preventing errors in a mass production system:

1. The contact method identifies product defects by testing the product's shape, size, color, or other physical attributes.
2. The fixed-value (or constant number) method alerts the operator if a certain number of movements are not made.
3. The motion-step (or sequence) method determines whether the prescribed steps of the process have been followed.

A methodic approach to build up poka-yoke countermeasures has been proposed by the Applied Problem Solving (APS) methodology, which consists of a three-step analysis of the risks to be managed:

1. identification of the need
2. identification of possible mistakes
3. management of mistakes before satisfying the need

This approach can be used to emphasize the technical aspect of finding effective solutions during brainstorming sessions.

2.4.3 Benefits of Poka Yoke Implementation

A typical feature of Poka Yoke solutions is that they don’t let an error in a process happen. But that is just one of their advantages. Others include:

- Less time spent on training workers;
- Elimination of many operations related to quality control.
- Unburdening of operators from repetitive operations;
- Promotion of the work improvement-oriented approach and actions;
- A reduced number of rejects;
- Immediate action when a problem occurs;
- 100% built-in quality control.

3. Implementation of Quality Tools

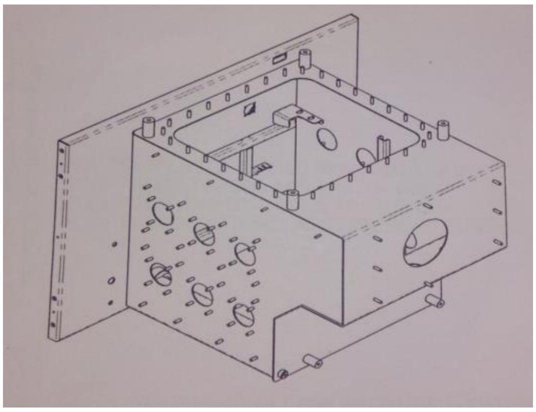


Fig 3.1 Product of workstation

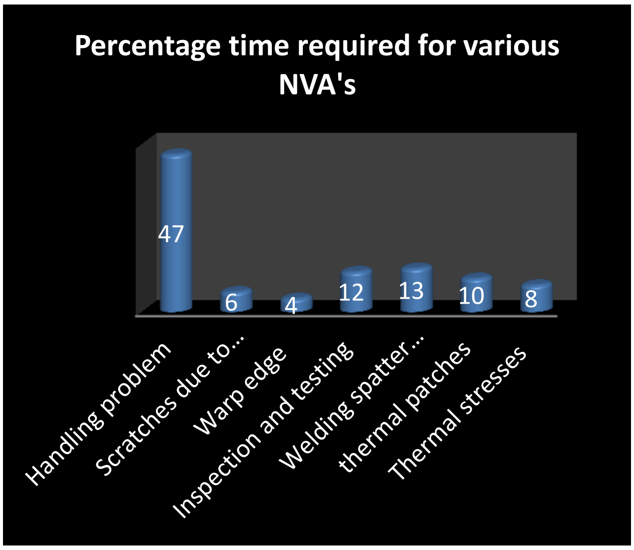
3.1 Data Analysis

From above data collected, Various NVA's associated with given processes are:

3.1.1 Pareto Analysis:

Table 3.2: Percentage Time Required for Various NVA's

SR NO.	NON VALUE ADDED ACTIVITY	PERCENTAGE TIME REQUIRED
1.	Handling problem	47%
2.	Scratches due to rough Handling	6%
3.	Warp edge problem due to handling of tank by belt and use of crane	4%
4.	Inspection and testing	12%
5.	Welding spatter problem	13%
6.	Thermal patches	10%
7.	Thermal stresses problem it changes dimensions between two brackets	8%



Graph 3.3: Pareto analysis of Associated NVA's

4. Design of fixture

From above analysis, major problem associated with given workstation is handling problem. So, designing of fixture for handling switchgear tank will play crucial role in eliminating these major problem and hence increase productivity.

Fig 4.1: Basic Model of Fixture

4.1 Design of Column

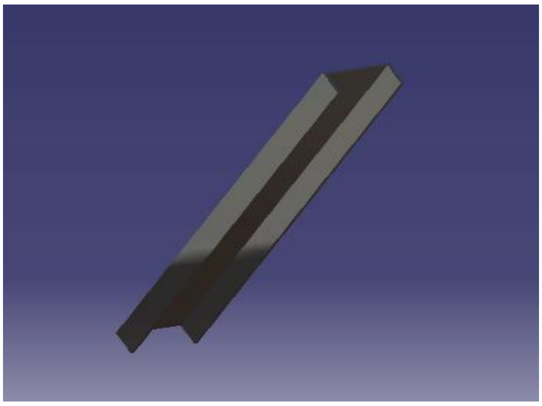


Fig 4.2: Standard ISMC100 Channel

Standard ISMC100 channel is selected.
Dimensions: 100*50*5 mm,
Material: Mild Steel, Self-weight: 9.56kg
Weight of switchgear tank = 150kg
E = 210Gpa =210*10^3 Mpa,
Syt=380 mpa
Compressive stress= Syt/2 =190 Mpa

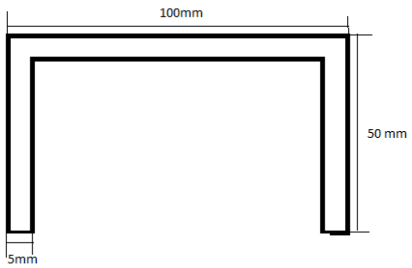


Fig4.3: C/S of ISMC100 Column

$$I = \frac{100*50^3}{12} - \frac{90*45^3}{12} = 358.22*10^3$$

Area=A= (100*50-90*45) = 950mm^2

M=P*L=2000*1000=2*10^6 N-mm

4.1.1 Compressive stress

$$\sigma c = \frac{P}{A} = \frac{4*10^3}{950} = 4.20\ N/mm^2$$

4.1.2 Bending stress

$$\frac{M}{I} = \frac{\sigma}{y}$$

$$\sigma = \frac{2000*10^3*25}{358.22*10^3} = 13.95\ N/mm^2$$

As the maximum stress is less than allowable
Hence, design is safe

4.1.3 Buckling Load

$$Pe = \frac{4\pi^2 EI}{L^2} = \frac{4\pi^2*210*10^3*358.22*10^3}{1000^2}$$
$$= 2.96*10^3 KN$$

As buckling load is greater than actual, design is safe.

4.2 Design of pin

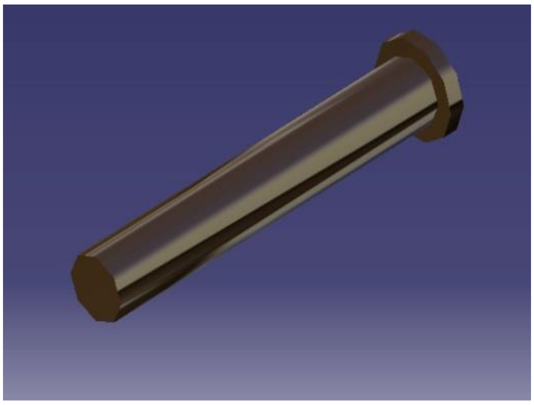


Fig 4.4: Design of Pin

Material: EN8
Material specification:-
Yield stress= Syt =465 N/mm^2
Hardness=201-255BHN
Compressive and tensile stress:
σt = σc = Syt/FOS=465/2=232.5 N/mm^2
Shear stress τ=0.5*σt =0.5*232.5=116.25 N/mm^2

4.2.1 Calculation of diameter using direct shear

$$\tau = \frac{P}{2*\frac{\pi d^2}{4}}$$

$$116.25 = \frac{4*10^3}{2*\frac{\pi d^2}{4}}$$

d=4.68 ≈ 5mm

4.2.2 Dimension of pin in Torsion

Considering FOS = 6, τ = 38.34

$$\tau = \frac{16T}{\pi d^3}$$

T = 400*1000 = 400000 N.mm

$$38.34 = \frac{16*400000}{\pi d^3}$$

d = 37.46 mm ≈ 40 mm
Taking higher dimension d = 40 mm

Conclusions

As per above project work and fixture design, we can conclude that

1. We can reduce efforts of workers by using fixture and we can also neglect handling problem

2. Due to suitability in process, it reduces time required to manufacture switchgear tank and hence production rate increases

3. Overall result will be improvement in quality and productivity of switchgear tank welding.

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