Reducing Wastages in Pump Manufacturing Processes through Lean Manufacturing Concept

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Abstract--- *Lean manufacturing is a systematic approach to process improvement. The method is based on finding and reducing waste coupled with continuous improvement. It was first developed by Toyota, but now applied to many diverse industries and businesses. An attempt has been made to apply lean manufacturing methodology in a leading pump manufacturing company, analyzing the seven wastages namely over-production, defects and their correction, inventory, transportation, waiting, motion and over-processing. The work concentrates on the activities in fettling, winding section, component stores and assembly section. To determine and reduce defects in winding section, Cause and effects diagram is constructed. Comparison is made on quality and productivity before and after implementing lean manufacturing. Proper transportation, material handling and storage systems are proposed to improve quality in fettling operations. Kanban cards are introduced to control the inventory level in stores, reducing the wastages.*

Keywords--- *Lean Manufacturing, Kanban Card, Visual Control, Standard Operating Procedure and Six-Sigma.*

I. INTRODUCTION

1.1. Lean Manufacturing

Lean manufacturing can be defined as “The production of goods using less of everything by reducing wastes and increasing value added activities”. If it doesn’t add value, it adds costs. In the pump manufacturing unit, the defect rate observed is little bit on the higher side which is a big concern for the management. Through lean manufacturing concept, the seven wastages encountered in manufacturing processes can be eliminated, which leads to the improvement in quality and productivity. The ultimate goal of a lean organization is to create a smooth and high quality organization that is able to produce finished products concerning the customers demand in the quality looked-for with no waste.

1.2. History of Lean Manufacturing

Many of the concepts in Lean Manufacturing originate from the Toyota Production System (TPS) and have been implemented gradually throughout Toyota’s operations beginning in the 1950's. By the 1980’s Toyota had increasingly become known for the effectiveness with which it had implemented Just-In-Time (JIT) manufacturing systems.

Today, Toyota is often considered one of the most efficient manufacturing companies in the world and the company that sets the standard for best practices in Lean Manufacturing. The term “Lean Manufacturing” or “Lean Production” first appeared in the 1990 book *The Machine that Changed the World*.

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Lean Manufacturing has increasingly been applied by leading manufacturing companies throughout the world, lead by the major automobile manufactures and their equipment suppliers. Lean Manufacturing is becoming an increasingly important topic for manufacturing companies in developed countries as they try to find ways to compete more effectively against competition from Asia.

In a 2009 survey by Industry Week Magazine, U.S. companies implementing lean manufacturing reported a median savings of 7% of Cost of Goods Sold (COGS) as a result of implementing lean.

Another way of looking at Lean Manufacturing is that it aims to achieve the same output with less input – less time, less space, less human effort, less machinery, less material, less cost.

When a U.S. equipment manufacturing company, Lantech, completed the implementation of lean in 1995, they reported the following improvements compared to their batch-based system in 1991:

- Manufacturing space per machine was reduced by 45%;
- Defects were reduced by 90%
- Production cycle time was reduced from 16 weeks to 14 hours - 5 days; and
- Product delivery lead time was reduced from 4-20 weeks to 1-4 weeks

Lean Manufacturing has endeavoured to rationalize production by:

- Completely eliminating waste in the production process
- To build quality into the process
- To reduce costs - productivity improvements
- To develop its own unique approach toward corporate management
- To create and develop integrated techniques that will contribute to corporate operation.

A. 1.3. Key Principles of Lean Manufacturing:

Key principles behind Lean Manufacturing can be summarized as follows:

1.3.1. Recognition of waste – The first step is to recognize what does and does not create value from the customer's perspective. Any material, process or feature which is not required for creating value from the customer's perspective is waste and should be eliminated. For example, transporting materials between workstations is waste because it can potentially be eliminated.

1.3.2. Standard processes – Lean requires an the implementation of very detailed production guidelines, called Standard Work, which clearly state the content, sequence, timing and outcome of all actions by workers. This eliminates variation in the way that workers perform their tasks.

1.3.3. Continuous flow – Lean usually aims for the implementation of a continuous production flow free of bottlenecks, interruption, detours, backflows or waiting. When this is successfully implemented, the production cycle time can be reduced by as much as 90%.

1.3.4. Pull-production – Also called Just-in-Time (JIT), Pull-production aims to produce only what is needed, when it is needed. Production is pulled by the downstream workstation so that each workstation should only produce what is requested by the next workstation.

1.3.5. Quality at the Source – Lean aims for defects to be eliminated at the source and for quality inspection to be done by the workers as part of the in-line production process.

1.3.6. Continuous improvement – Lean requires striving for perfection by continually removing layers of waste as they are uncovered. This in turn requires a high level of worker involvement in the continuous improvement process.

II. 1.4. Lean Manufacturing Concept:

A. 1.4.1. Value Creation and Waste :

In Lean Manufacturing, the value of a product is defined solely based on what the customer actually requires and is willing to pay for. Production operations can be grouped into following three types of activities:

Value-added activities are activities which transform the materials into the exact product that the customer requires.

Non value-added activities are activities which aren't required for transforming the materials into the product that the customer wants. Anything which is non-value-added may be defined as waste. Anything that adds unnecessary time, effort or cost is considered non value-added. Another way of looking at waste is that it is any material or activity for which the customer is not willing to pay. Testing or inspecting materials is also considered waste since this can be eliminated insofar as the production process can be improved to eliminate defects from occurring.

Necessary non value-added activities are activities that don't add value from the perspective of the customer but are necessary to produce the product unless the existing supply or production process is radically changed. This kind of waste may be eliminated in the long-run but is unlikely to be eliminated in the near-term.

Research at the Lean Enterprise Research Centre (LERC) in the United Kingdom indicated that for a typical manufacturing company the ratio of activities could be broken down as follows:

Value-added activity 5%

Non value-added activity 60%

Necessary non value-added activity 35%

Total activities 100%

This implies that up to 60% of the activities at a typical manufacturing company could potentially be eliminated.

B. 1.5. Main Kinds of Waste:

Originally 7 main types of waste were identified as part of the Toyota Production System. However, this list has been modified and expanded by various practitioners of lean manufacturing and generally includes the following:

1.5.1. Over-production – Over-production is unnecessarily producing more than demanded or producing it too early before it is needed. This increases the risk of obsolescence, increases the risk of producing the wrong thing and increases the possibility of having to sell those items at a discount or discard them as scrap.

1.5.2. Defects& their Correction – In addition to physical defects which directly add to the costs of goods sold, this may include errors in paperwork, provision of incorrect information about the product, late delivery, production to incorrect specifications, use of too much raw materials or generation of unnecessary scrap. Correction is when something has to be re-done because it wasn't done correctly the first time. This not only results in inefficient use of labour and equipment but the act of re-processing often causes disruptions to the smooth flow of production and therefore generates bottlenecks and stoppages.

1.5.3. Inventory – Inventory waste means having unnecessarily high levels of raw materials, works-in-progress and finished products. Extra inventory leads to higher inventory financing costs, higher storage costs and higher defect rates.

1.5.4. Transportation - Transportation includes any movement of materials that does not add any value to the product, such as moving materials between workstations. Transportation between processing stages results in prolonging production cycle times, the inefficient use of labour and space and can also be a source of minor production stoppages.

1.5.5. Waiting – Waiting is idle time for workers or machines due to bottlenecks or inefficient production flow on the factory floor. Waiting also includes small delays between processing of units.

1.5.6. Motion – Motion includes any unnecessary physical motions or walking by workers which diverts them from actual processing work. For example, this might include walking around the factory floor to look for a tool, or even unnecessary or difficult physical movements, due to poorly designed ergonomics, which slow down the workers.

1.5.7. Over-processing – Over-processing is unintentionally doing more processing work than the customer requires in terms of product quality or features – such as polishing or applying finishing on some areas of a product that won't be seen by the customer.

1.6. Lean Manufacturing Tools & Methodologies:

1. Kaizen Rapid Improvement Process
2. The Five S's
3. Total Productive Maintenance (TPM)
4. Cellular Manufacturing
5. Kanban Card
6. Visual Management
7. Standard Operation Procedures
8. Value Stream Mapping
9. Six sigma

II. LITERATURE REVIEW

Earlier works related to lean manufacturing application were studied. The details of some of the reports are presented here:

[1] Mohammad Taleghani has published a paper entitled “Key for implementing the lean manufacturing system”. The purpose of the paper is to provide a historical review for the role of management in implementation of lean thinking in a lean manufacturing environment. Two basic lines of lean manufacturing are “respect to the workforce" and "waste elimination" which is introduced in this paper and how these factors can cause an effective leadership during implementations. Then, it is described that how companies use the benefits of lean tools in their conception of lean implementations, and what factors involve managers with culture and leaderships issues. Also, this study implies that not only it is necessary to implement most of the technical tools but an organizations culture needs should change too.

[2] Norani Nordin, Baba Md Deros and Dzuraidah Abd Wahab has published one journal entitled **“**A Survey on Lean Manufacturing Implementation in Malaysian Automotive Industry. This paper examines the drivers and barriers that influence the implementation of lean manufacturing. The survey was performed on sixty Malaysian automotive components manufacturing firms. The respondents were chosen from those who are directly involved with lean manufacturing practices such as production and quality personnel. The findings show that most of the respondent firms are classified as in-transition towards lean manufacturing practice

[3] Indra Gunawan presented a paper **“**Implementation of Lean Manufacturing through Learning Curve Modelling for Labour Forecast” In this paper; an Implementation of lean manufacturing through learning curve modelling for labour forecast is discussed. Firstly, various learning curve models are presented. Then the models are analyzed in terms of their advantages and limitations. As a case study, the learning curve modelling is presented with the data derived from a production company. With the application of the learning curve, labour need can be more accurately predicted and scheduled on time.

[4] Rose, A.M.N., Deros, B.Md., Rahman, M.N.Ab. & Nordin, N.presented a paper namely “Lean manufacturing best practices in SMEs” according to them, Last two decades had witnessed explosion of researches into the area of manufacturing improvement such as lean manufacturing, total quality management, total productive maintenance and their application within various manufacturing companies such as automotives, electronics, plastics components and etc. It was proven that lean manufacturing was considered as the best manufacturing system in the 21st century. The review is focused on SME definitions and characteristics. This is followed by reviewing the lean practices and discusses them based on SMEs’ capabilities. The aim of this paper is to present feasible lean practices for lean implementation in SMEs. There are seventeen lean practices which could be considered are feasible and relevant to the SME characteristics. The proposed practices were based on three categories; least investment, feasible to apply in SME and recommended by researchers.

III. IMPLEMENTING LEAN MANUFACTURING

From the process layout studied in the previous chapter, it was found that the main areas of defect generation are under the activities in fettling, winding section, component stores and assembly section. The work concentrates on these areas to reduce wastages and defects.

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3.1. Fettling:

Fettling is the process of removing sand, adhering to castings by hammering, tumbling or shot blasting. It is done to remove the burr and protrusions on the cast component.

3.1.1. Problem identified:

The main problems identified in the activities of fettling are

- Defects during transportation
- Improper material handling
- Improper storage

Due to these problems, chances of components being defective are high. In order to avoid the risk of loss in quality and productivity, control measures are proposed and implemented.

3.1.2. Remedial Actions:

- Proper arrangement and separation of each component with card board pieces to avoid direct contact between components.
- After fettling operations parts are arranged in racks.

3.2. Winding Section:

In the winding section, internal rejection is in increasing trend. The delivery of pumps from sub unit to assembly unit is affected due to high amount of reworks in pump assembly. From the chart major defects are noticed.

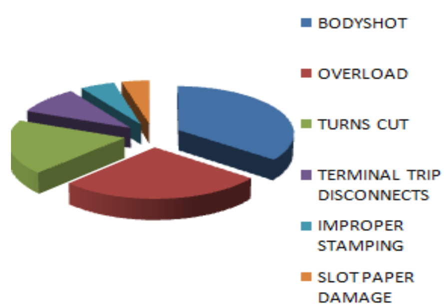

Fig: 3.1. Category of defects encountered in winding section

TABLE 3.1 DEFECTS IN PPM

BODYSHORT	7583
OVERLOAD	5756
TURNS CUT	3985
TERMINAL TRIP DISCONNECTS	2048
IMPROPER STAMPING	1107
SLOT PAPER DAMAGE	885

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From figure 3.1, it is found that the first three defects, i.e. body shot, over load and turns cut contribute more *than 50% pump defects.*

3.2.1. Methodology:

Defects reduction is the primary goal of this work, which is done using six sigma methodologies. Six sigma is a business strategy used to improve business profitability, effectiveness and efficiency of all operations to meet the customer needs and expectations. The DMAIC frame work of six sigma focuses on structured approach to solve the problem, thereby defect reduction is done step by step.

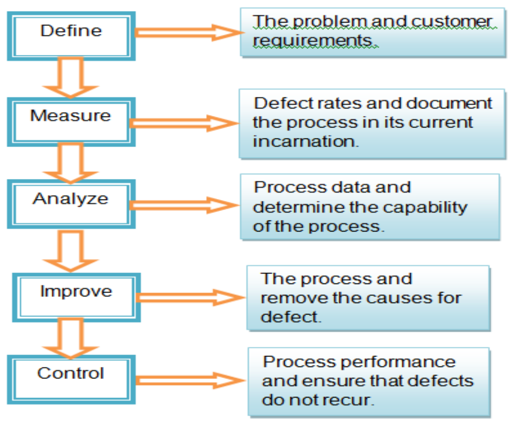

Fig: 3.2 DMAIC

3.2.2. Define Problem statement:

The defect rate of the component 4 inch submersible pump in production unit is very high, taking up to 7583PPM

3.2.3. Measure:

The measure phase is focused on the data collection on the defects which affect the pump assembly. The defects which affect the pump production and assembly are shown in table 3.1

3.2.4. Body Short:

While testing the resistance of the motor winding is tested by using an ohmmeter on the proper terminals in the control box. The resistance should match the ohms specified in the data sheet. If it's too low the motor winding may be shorted. If the ohmmeter needle doesn't move, indicating high or infinite resistance, there is an open circuit in the motor winding or cable.

3.2.5. Over Load:

If the fuses blow or overloads trip while the well pump is testing, check line amps. If more than 5% above the manufacturer's nameplate value, the pump is overloading, this indicates a defective well pump and / or motor.

3.2.6. Slot Paper Damage:

The slot paper is inserted inside the stator to protect turns from touching the stator body and if the slot paper gets

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damage, body shot or overload occurs.

The monthly production rate of the industry, defect level in numbers and PPM level are shown in the table 4.2.

TABLE 3.2 MONTHLY PRODUCTIONRATES

MONTH	PRODUCTION RATE	DEFECTS IN NUMBERS	DEFECTS IN PPM
JUNE	3400	50	14705
JULY	3095	39	12600
AUGUST	4500	43	9555

3.3. Factors Affecting Defects:

The factors affecting defects in the pump are

- Improper stamping
- Increase or decrease of turns
- Terminal trip disconnect
- Slot paper damage
- Poor threading on stator body

3.4. Analyze:

The analysis phase is focused on the data collected in the measure phase. The analysis is initiated with the cause and effect diagram to find out the root cause of the defect.

3.4.1. Cause and Effect Analysis:

Based on the observations and problem statement, a brain storming session is conducted to identify the causes for pump rework due to body shot. The possible causes are analysed for their relationship the problem. The same is shown in figure.3.3.

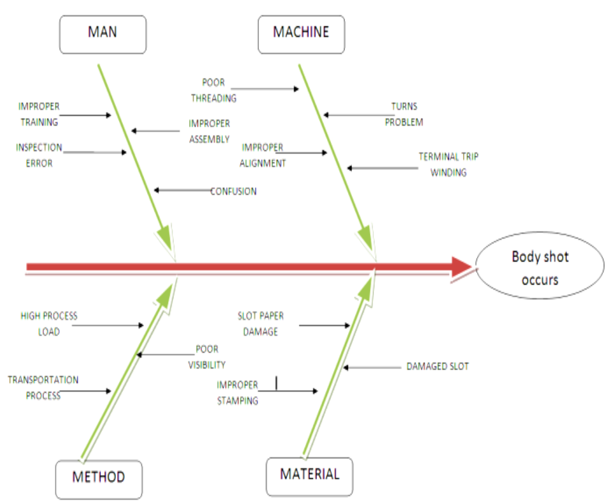

Fig: 3.3.Cause and effect diagram

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3.5. Six Sigma Calculation:

(Before Implementing Lean Manufacturing)

Total no. of components produced= 3665

Total no. of defective components= 44

Defects per unit= no. of defectives/ no. of units= 44/3665= 0.012005457

Yield=1-DPU=1-0.012005457=0.987995or 98.7995%

Defects per opportunity= no. of defects/(no. of units × no. of opportunities) = 44/(3665 × 4)= .003001364256

Defects per million opportunity= DPO × 10^6= 3001.36

From sigma conversion table, for 3001.36 DPMO sigma value is 4.3

Table: 4.3 Monthly production rates before implementing lean manufacturing

MONTH	PRODUCTION RATE	DEFECTS IN NUMBERS
JUNE	3400	50
JULY	3095	39
AUGUST	4500	43

3.6. Improve:

The improve phase focuses on the factors analyzed in the analysis phase to give out the required solution to meet the objective. From cause and defect diagram the various causes for body shot, overload and few others are discussed for improvement.

Table: 4.4 Monthly production rates after implementing lean manufacturing

MONTH	PRODUCTION RATE	DEFECTS IN NUMBERS
SEPTEMBER	4100	26
OCTOBER	4350	20

3.6.1. Six Sigma Calculation:

(After Implementing Lean *Manufacturing)*

Total no. of components produced= 4225

Total no. of defective components= 23

Defects per unit= no. of defectives/ no. of units=23/4225= 0.00544379

Yield= 1-DPU= 1-0.00544379= 0.9945 or 99.45%

Defects per opportunity= no. of defects/(no. of units × no. of opportunities)

= 23/(4225 × 4)= .0013609467

Defects per million opportunity= DPO × 10^6= 1360.9467

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From sigma conversion table, for 1360.9467 DPMO sigma value is 4.5.

3.7. Control:

The control phase, the last step of DMAIC should progress after the improvements are standardized. Standardization includes,

Continuous monitoring and measurement of processes

Updation of design standards

Updation of control plans

Updation of operation standards and

Extensive education and training to operators.

The proposed activities should be thoroughly followed for improvement in quality. Continuous improvement of processes can be achieved through proper training and extensive educational programme for employees.

3.8. Component Store:

3.8.1. Problem Identified:

Improper arrangement and lack of knowledge about the inventory level in stores leads to high amount of wastages.

3.8.2. Remedial Action:

In order to avoid the wastages, Kanban cards are installed in the component stores.

3.8.3. Kanban Card:

Kanban is one of most popular tools in lean manufacturing. This is a simple concept, but very effective. Kanban mainly focus on the reduction of overproduction. There are mainly two types of kanbans. They are

- Withdrawal Kanban and
- Production Kanban

Withdrawal kanban is the common type, which is actually a request from the process before that. This specifies the quantity that the succeeding process should take from the process before that.

On the other hand production kanban specifies the amount of products to be made in the next process with the goods created in the process before that.This might take a form of a simple card which has the details of the product, quantity and the storage location of that particular product. This even may be a sophisticated electronic data exchange process. No matter what, the final objective must be achieved and it should be an efficient process.

IV. ASSEMBLY SECTION

4.1. Visual Management :

Visual Management systems enable factory workers to be well informed about production procedures, status and other important information for them to do their jobs as effectively as possible. Large visual displays are generally much more effective means of communication to workers on the factory floor than written reports and guidelines and therefore should be used as much as possible. When it comes to improving compliance with a process, visual presentation helps the team better understand a complicated process including the correct sequence of events, the correct way to perform each action, internal and external relationships between actions, and other factors. These visual tools may include the following:

1. **Visual Displays** - Charts, metrics, procedures and process documentation which are reference information for production workers. For example, trend chart of yield performance, percentage variation of defect rate, month-to-date shipping volume status, etc.

2. **Visual Controls** – Indicators intended to control or signal actions to group members. This may include production status information, quality tracking information, etc. For example, colour-coded panel for temperature or speed setting control limits that help an operator quickly identify process is out of the control range. Kanban cards are another example of visual controls.

3. **Visual process indicators** – These communicate the correct production processes or flow of materials. For example, this would include the use of painted floor areas for non-defective stock and scrap or indicators for the correct flow of materials on the factory floor.

In order to avoid wrong assembly of components, visual charts are displayed in assembly section. This provides a clear idea about each step to be carried out while assembling

V. RESULTS AND DISCUSSIONS

After implementing lean manufacturing concept in the activities in fettling, winding section, component store and assembly considerable improvements are observed. With the new transportation method the defect occurring due to transportation are completely eliminated.

Use of proper storage system after fettling process reduces the chance of component being defective. Applying six sigma methodology in winding section to reduce the pump rework and to ensure that the defect is reduced in target level.

Defect per million opportunities reduced by 54%

Improvement of six sigma value from 4.3 to 4.5

Increase in total yield is from 98.7995% to 99.45%.

Kanban cards avoid high inventory level and reduced by 80%.

Visual control displays will eradicate the wrong assembly in the concerned section

In order to sustain the results achieved by this work, the improvements are standardized. Extensive education and training to operators should be done. A quality circle should be formed within the company to improve the quality and productivity of the product

VI. CONCLUSION

In the pump manufacturing unit, the defect rate observed was little bit on the higher side which was a big concern for the management.

Through lean manufacturing concept, the seven wastages encountered in manufacturing processes were eliminated, which lead to the improvement in quality and productivity. The integration of lean manufacturing concept is widely demanded by industries in the present scenario.

Lean manufacturing concept is applied in the activities in fettling, winding section, component store and assembly section of a pump manufacturing unit. By introducing this concept factors affecting the defects and wastages in the unit are studied and analyzed.

The work aims to improve quality and productivity by reducing wastages, there by satisfying the customer needs. The work deals with reducing defects and wastages in activities under fettling, applying six sigma methodology in winding section, installing kanban cards in component store, display of visual charts in assembly and proposed standard operation procedure for assembling.

Through this work, the pump rework is successfully reduced at pump assembly section, which helps to produce defect free pumps. With this work, the company is benefited in terms of quality, productivity, cost reduction, timely delivery and customer delight.

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