Application of Lean Manufacturing to Achieve Higher Productivity in Precision Surface Equipment Industries

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Abstract - Lean manufacturing is now one of the most powerful manufacturing systems in the world. Numerous plants around the world have attempted to implement or adopt it to enhance their efficiency. Manufacturing organizations have adopted the concept of lean manufacturing in order to improve the quality of their products and reduce their wastes. This is done by ensuring that products are assessed or evaluated at each and every stage hence costs are reduced. However, little studies regarding lean manufacturing have been done in India small scale Industry especially in the Precision surface equipment industry. The purpose of this study is to investigate the approach of adopting lean, the tools and techniques implemented, the changes in the organizations, the problems encountered as well as the lessons learnt. This is perhaps the first study that investigates the actual implementation of lean manufacturing in the Precision surface equipment industry. Our research on applicability of lean manufacturing helped the organization to visualize the different types of wastes generated in the organization and future possibilities of eliminating or reducing them. The research was administered with leading Precision surface equipment industry in India using secondary data and observations. The outcome of this observation reflected that an industry may gain higher productivity and profitability by proper application of lean manufacturing. A general overview over this development is given in this.

Key Words: Precision Surface Equipment Industry, 5's'' Implementation, Lean Manufacturing, Productivity, Wastages elimination.

1. INTRODUCTION

Lean Manufacturing has recently become pervasive as the primary strategy for manufacturing performance enhancement. Many companies now realize that business success in the short, medium and long term is predicated upon outstanding performance in the quality of products and efficiency of manufacturing operations. These companies recognize that consistent and disciplined application of Lean Manufacturing strategies, with the emphasis on waste elimination and process streamlining, can offer a steady path towards business excellence. The primary objective of lean manufacturing is to assist manufacturers who have a desire to improve their company's operations and become more competitive through the implementation of different lean manufacturing tools and techniques. Generally in an industry more focus is given on profit. Though there are different issues involved in cost reduction internally spent by an industry through finding wastages, preventing and correcting defective work would result in huge savings [1]. In this competitive world of "Globalization" of market, every industry has to ensure optimum utilization of all resources to survive. The application of lean manufacturing concepts to the continuous production/ process sector has become a necessity. After World War II, Japanese manufacturers, particularly in the automotive industry, were faced with the dilemma of shortages of material, financial, and human resources. Eiji Toyoda and Taiichi Ohno at the Toyota Motor Company in Japan pioneered the concept of the "Toyota Production System", or what is known today in the US as "Lean Manufacturing." The basic idea behind the system is eliminating waste. Waste is defined as anything that does not add value to the end product from the customer's perspective [6]. Lean Manufacturing is a group of methods, which are being increasingly implemented around the world, that aim to eliminate waste and inefficiency from the manufacturing process, leading to lower costs and greater competitiveness for manufacturers. In a recent survey, approximately 36% of U.S. based manufacturing companies have implemented lean or are in the process of implementing lean [12].

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2. Background of the research problem

Lean manufacturing is a proven technique that allows work to be performed without bottlenecks or delays. In the lean environment, these activities do not add value to the product and considered a waste. The lean manufacturing methodologies eliminate the wasteful activities by linking and balancing equal amounts of work steps together, enabling products to be consume directly into the next step, one piece at a time until completed. The sum of the work time minus the added queue and wait time required to progress through the manufacturing processes is always shorter than the time required to route products through a batch manufacturing. Physically, locating manufacturing processes close together allows the complete output of one process to be directly consumed into the next, reducing inventories and cycle time. This physical linkage allows the standard work tasks to be accomplished in a sequential and progressive manner at each workstation until the product completely processed. Wait and queue time normally associated with batches routed the different manufacturing departments is greatly reduced or eliminated.

Most of benefits lead to lower unit production costs – for example, more effective use of equipment and space leads to lower depreciation costs per unit produced, more effective use of labor results in lower labor costs per unit produced and lower defects lead to lower cost of goods sold. In a 2004 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 [12]. We believe that the savings many actually be higher for companies in Vietnam considering the higher levels of waste which they typically have compared to U.S. based manufacturers. 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 materials, less costs. 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 [13]:

- 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.

3. Problem Statement

In the manufacturing process, there are so many wastes that can affect the profit of the business. Waste is defined as anything that does not add value to the end product from the customer's perspective. The manufacturer must minimize the waste during producing the product so that the profit of the business can generate highly and the production cost can be minimized. The main task in this case is" How can Lean methodology be effectively applied to improve the performance of Precision surface Equipment industry**?**"

4. Objective of the Study

To examine the present level of applying lean manufacturing in precision surface equipment industries in India. Improve productivity & house condition by to eliminating all waste in the production process & implementation of 5's. Besides, to identify and propose potential avenues for improving present level of lean manufacturing, to achieve a competitive advantage.

5. Literature Review on Lean Manufacturing

5.1 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[14]. 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 [15].

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.[5]

5.2 What is Lean Manufacturing?

Lean Manufacturing can be defined as "A systematic approach to identifying and eliminating waste through continuous improvement of the product at the demand of the customer." Taiichi Ohno once said that "Lean Manufacturing is all about looking at the time line from the moment the customer gives us an order to the point when we collect the cash. And we are reducing that time line by removing the non – value added wastes" (Ohno, 1988) [6]. Lean Manufacturing, also called Lean Production, is a set of tools and methodologies that aims for the continuous elimination of all waste in the production process. The main benefits of this are lower production costs, increased output and shorter production lead times. More specifically, some of the goals include:

1. **Defects and wastage** - Reduce defects and unnecessary physical wastage, including excess use of raw material inputs, preventable defects, costs associated with reprocessing defective items, and unnecessary product characteristics which are not required by customers;
2. **Cycle Times** - Reduce manufacturing lead times and production cycle times by reducing waiting times between

processing stages, as well as process preparation times and product/model conversion times;

3. **Inventory levels** - Minimize inventory levels at all stages of production, particularly works-in-progress between production stages. Lower inventories also mean lower working capital requirements;

4. **Labor productivity** - Improve labor productivity, both by reducing the idle time of workers and ensuring that when workers are working, they are using their effort as productively as possible (including not doing unnecessary tasks or unnecessary motions);

5. **Utilization of equipment and space** - Use equipment and manufacturing space more efficiently by eliminating bottlenecks and maximizing the rate of production though existing equipment, while minimizing machine downtime;

6. **Flexibility** - Have the ability to produce a more flexible range of products with minimum changeover costs and changeover time.

7. **Output** – Insofar as reduced cycle times, increased labor productivity and elimination of bottlenecks and machine downtime can be achieved, companies can generally significantly increased output from their existing facilities. [5]

5.3 Wastes in Lean Manufacturing

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. **Over-production** – Producing items for which there are no orders, which generates such wastes as overstaffing and storage and transportation costs because of excess inventory.

2. **Defects** – Production of defective parts or correction. Repair or rework, scrap, Defects replacement production, and inspection mean wasteful handling, time, and effort [3].

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.

4. **Transportation** - Transportation includes any movement of materials that does not add any value to the product, such as moving materials between workstations. The idea is that transportation of materials between production stages should aim for the ideal that the output of one process is immediately used as the input for the next process. Transportation between processing stages results in prolonging production cycle times, the inefficient use of labor and space and can also be a source of minor production stoppages.

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. Waiting results in a significant cost insofar as it increases labor costs and depreciation costs per unit of output.

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.

7. **Correction** – Correction, or reprocessing, 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 labor and equipment but the act of re-processing often causes disruptions to the smooth flow of production and therefore generates bottlenecks and stoppages. Also, issues associated with reworking typically consume a significant amount of management time and therefore add to factory overhead costs.

8. **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.

9. **Knowledge Disconnection** – This is when information or knowledge isn't available where or when it is needed. This might include information on correct procedures, specifications, ways to solve problems, etc. Lack of correct information often leads to defects and bottlenecks. For example, unavailability of a mixing formula may potentially suspend the entire process or create defective items due to time-consuming trial-and-error tests [5].

5.4 Lean Manufacturing Concepts

5.4.1 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

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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. For example, high levels of inventory may be required as buffer stock, although this could be gradually reduced as production becomes more stable.

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 [16]:

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.

5.5 What is a 5's

5's is a system to reduce waste and optimize productivity through maintaining an orderly workplace and using visual cues to achieve more consistent operational results. Implementation of this method "cleans up" and organizes the workplace basically in its existing configuration, and it is typically the first lean method which organizations implement.

The 5's pillars are Sort (Seiri), Set in Order (Seiton), Shine (Seiso), Standardize (Seiketsu), and Sustain (Shitsuke) [3].

5.5.1 The Benefits of the 5's System

Increases in productivity:

Reduces lead times thereby improving product delivery times

Reduces equipment downtime, maintenance and cycle time

Improves daily and shift startup times and reduces changeover time

Reduces the amount of time wasted searching for tools and equipment

Increases in quality:

Improves quality by reducing the amount of errors/defects

The pleasantries of the simplified work environment increases employee moral

Reduction in cost:

Provides cost-savings by reducing inventory, storage fees and space requirements

Improves safety thereby reducing the cost of worker injuries

Reduces the amount of scrap thereby reducing production cost [11]

6. METHODOLOGY

Inclusive literature review was carried out on Lean Manufacturing as below flow diagram shown. Then a PSE manufacturing industry was selected to carry out the implementation study. In the first step site tour was conducted in order to get an idea about the existing products and the overall process of the company. The major component Bed Plate & Surface Plate were then selected which produced 10 in no's in a month which are used for application of lean manufacturing by collecting the relevant data. In order to carry out this task, cross-functional team members' were formed. They were divided into zone wise and were responsible for individual project as like work place improvement, reduction in internal rejection & rework, to implement maintenance practice, inventory control & reduce project lead time'. We know different non-value added works have a great impact on productivity. Because of non value added activities, increase in standard process time occurs. Both for including and excluding non productive activities, standard was found out. Then current state of lean manufacturing has been analyzed and various improvement proposals were identified to reduce the non-value adding waste. After that effective suggestion and recommendations were made.

Study of Lean Manufacturing

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Selected Organization for Lean Implementation

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Developed Current Status of Lean Manufacturing & Prepare road map for PSE industry at initial level

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Selection of Parameters & Factors of Lean Manufacturing in Organization

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Identification of Components.

↓

Implementation of 5's

↓

Development of QA Matrix

↓

Inventory Control

↓

Recommended Suggestions to Apply Lean Manufacturing in the PSE Industry

Fig. 1 flow diagram of project methodology

6.1 Selection of Parameters & Factors of Lean Manufacturing in PSE Industry :

- House Condition Daily
- Performance Data Collection
- Production/ Productivity
- Quality
- Breakdown
- Changeover.
- Planned Time/ Uptime

6.2 Identification of Components.

These are major component selected for implementation of lean manufacturing in PSE industry:

1) Bed plate 2) Surface Plate 3) Box Angle Plate 4) Angle Plate, 5) Fitter Bar 6) Straight Edge

7. Results and Discussion

Looking at the current state of manufacturing several common causes were identified: (a) large inventories, (b) the difference between the total production lead-time and the value added time (c) each process producing to its own schedule, (d) over production, (e) Excess Motion, (f) Waiting time and other non productive time were observed and recorded carefully. As the initial step a site tour was conducted with the management team and followings observations were made.

7.1 5's Implementation

First off all 5's assessment sheet was prepared which is shown in table and then on the basis of this audit was done in PSE industry, then after current status was found out 24 %.

Table-1: 5's Assessment sheet at initial stage

5's Assessment sheet at initial stage							
Level	**Baseline 0**	**Beginner 1**	**Basic 2**	**Visual 3**	**Systematic 4**	**Preventive 5**	**Score**
Sort	Unsafe items in work area	Needed and unneeded items found in work area	Needed /un-needed items separated, unneeded tagged	Red tag area created, all unneeded items removed	List of needed items developed, maintained, posted	Un-needed items are not allowed in area	1
Set in Order	Placement of items causes unsafe conditions	Needed and unneeded items are placed randomly throughout the workplace	Needed items stored in an organized manner	Needed items have dedicated positions that are clearly indicated	Needed items can be retrieved within (cell target) seconds and (cell target) number of steps	Method for adding/deleting indicators for needed items	1
Shine	Spills, waste, trash, etc. produce unsafe conditions	Work area and machines are not cleaned on a regular basis	Area and equipment cleaned daily	Standard work layout posted and maintained	Daily inspection of plant and area occurs	Root cause sources of dirt, grease & spillage have been eliminated	1
Standardize	No work methods or procedures documented	Methods of work not completely documented	Methods of work documented but not consistently used	Methods of work posted and consistently used by some cell team members	Methods of work consistently used by all cell team members	Methods of work are regularly reviewed and improved	2
Sustain	No routine review/correction of unsafe conditions	Occasional, unscheduled 5's activity	5's activities conducted on regular basis	5's assessment conducted occasionally and results posted	5's assessment conducted on a regular basis and recurring problems are identified	Root causes of problems revealed by 5's assessment are identified and eliminated	1
TOTAL SCORE (MAX. OF 25)							**6**
OVERALL 5 S' SCORE (INDEXED TO 100)							**24.00 %**

Then 5's campaign schedule was prepared on the basic of which internal audit schedule done weekly. Then internal audit was done on the basis of planned schedule & 5's assessment sheet after audit NC sheet created & given target date for closing the NC to each department for further improvement.

Team formation is done for lean manufacturing as per below table

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Table -2 Team Formations for Lean Manufacturing in PSE Industry

Team Formation For Lean Manufacturing In Pse Industry					
Sr.No	1	2	3		4
Project Name	Work Place Improvement	Reduction In Internal Rejections	To Implement Maintenance Practices	To Reduce Inventory Level	Reduce Poject Lead Time
Team Leader	Team Leader	Team Leader	Team Leader	Team Leader	Team Leader
Team Member	Team Members	Team Member	Team Member	Team Member	Team Members

Then 5's audit score sheet was prepared at monthly basis which shown in table below.

Table 3 : 5 S's Internal Audit Score Sheet

INTERNAL AUDIT SCORE SHEET										
S No	Zone No	Zone Leader	Audit Score							
			MARCH 2014				APRIL 2014			
			1st week	2nd week	3rd week	4th week	1st week	2nd week	3rd week	4th week
1	Z1	**Zone Leader 1**	54.00%	55.00%	62.00%	65.00%	62.00%	64.00%	64.00%	68.00%
2	Z2	**Zone Leader 2**	52.00%	50.00%	42.00%	52.00%	50.00%	52.00%	50.00%	46.00%
3	Z3	**Zone Leader 3**	64.00%	64.00%	44.00%	54.00%	58.00%	58.00%	62.00%	60.00%
4	Z4	**Zone Leader 4**	65.00%	68.00%	78.00%	75.00%	62.00%	65.00%	68.00%	70.00%
5	Z5	**Zone Leader 5**	48.00%	48.00%	42.00%	48.00%	59.00%	52.00%	50.00%	50.00%
6	Z6	**Zone Leader 6**	50.00%	60.00%	70.00%	72.00%	65.00%	62.00%	65.00%	69.00%
AVERAGE			55.5	57.5	56.33	61	59.33	58.83	59.83	60.5
Overall 5 S' Score (Indexed To 100)									**54.00%**	

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Graph for 5’s Internal Audit Score Sheet.

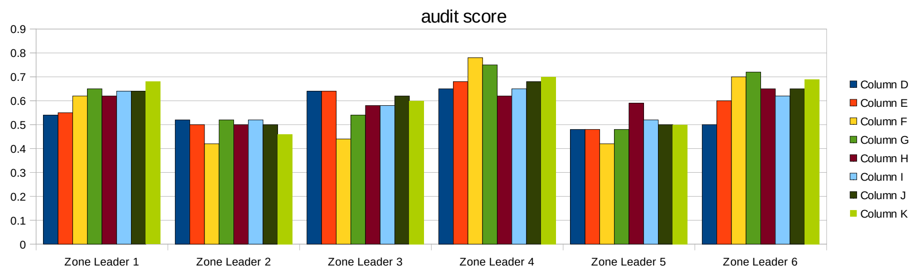

Fig.2: 5’s Internal Audit Score

The above activity done for all departments & after six month improvement assessment is calculated shown in table below

Table 4: 5’s Assessment sheet after implementation of 5's

5’s Assessment sheet after implementation of 5's							
Level	**Baseline 0**	**Beginner 1**	**Basic 2**	**Visual 3**	**Systematic 4**	**Preventive 5**	**Score**
Sort	Unsafe items in work area	Needed and unneeded items found in work area	Needed /un-needed items separated, unneeded tagged	Red tag area created, all unneeded items removed	List of needed items developed, maintained, posted	Un-needed items are not allowed in area	3.5
Set in Order	Placement of items causes unsafe conditions	Needed and unneeded items are placed randomly throughout the workplace	Needed items stored in an organized manner	Needed items have dedicated positions that are clearly indicated	Needed items can be retrieved within (cell target) seconds and (cell target) number of steps	Method for adding/deleting indicators for needed items	2.5
Shine	Spills, waste, trash, etc. produce unsafe conditions	Work area and machines are not cleaned on a regular basis	Area and equipment cleaned daily	Standard work layout posted and maintained	Daily inspection of plant and area occurs	Root cause sources of dirt, grease & spillage have been eliminated	3
Standardize	No work methods or procedures documented	Methods of work not completely documented	Methods of work documented but not consistently used	Methods of work posted and consistently used by some cell team members	Methods of work consistently used by all cell team members	Methods of work are regularly reviewed and improved	2.5

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Sustain	No routine review/correction of unsafe conditions	Occasional, unscheduled 5's activity	5's activities conducted on regular basis	5's assessment conducted occasionally and results posted	5's assessment conducted on a regular basis and recurring problems are identified	Root causes of problems revealed by 5's assessment are identified and eliminated	2
TOTAL SCORE (MAX. OF 25)							**13.5**
OVERALL 5's SCORE (INDEXED TO 100)							**54.00%**

Result: Highly satisfying results have been obtained after implementation of 5's. By this condition of shop floor improved & space utilization also improved & removal of waste of mass about 2000 kilograms and sold at the rate of Rs.20/kg and total amount of Rs 40000 have been accrued.

Red Tag area

Fig.-3: Developed Red Tag area after 5's implementation

BEFORE **AFTER**

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BEFORE

AFTER

GANGWAY & MACHINE LOCATION MARKING

Fig.-4: Shop floor improvement after implementation of 5's

7.2 DEVELOPMENT OF QA MATRIX:

In PSE industry highly rework & rejection rate occur for which first of all the problem of rejection & rework was found out, and then to these problems QA matrix prepared was prepared which is shown in Table-5. Then after analysis three major problems found out these are neck over size, neck under size & heavy tool marks. To find out the cause of these problems some QC tools where used i.e. fish bone diagram, IOM analysis, Pareto chart, why-why analysis. By fishbone diagram some causes were found out and means of IOM analysis & Pareto tool the major cause was found out, and to find out the root cause of these major causes why-why analysis was done in below table. Then action plan was prepared to solve these problems, for all three problems these analysis was done.

Table 5: Development of QA matrix

Development of QA Matrix												
Sr No.	Product	Defect	Receipt Stage	Top Roughing	Side Machining	Neck Roughing	Neck Final	T-Slot Machining	Top Finish	T Nut Entry	Drill /Tap	Length Machining
1	Fitter Bar / Bed Plate /Surface plate	Neck/Dim Over Size	No	No	No	Yes (5)	Yes (4)	No	No	No	Yes (2)	No
		Current control	*No*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
		Neck/Dim Under Size	No	No	No	No	Yes (8)	Yes (5)	No	No	Yes (1)	Yes (1)
		Current control	*No*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

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		Blow Holes	No	No	**Yes (3)**	No	No	**Yes (3)**	No	No	No	No
		Current control	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*No*
		Less Material	No	No	**Yes (1)**	No	No	No	No	No	No	No
		Current control	*N/A*	No	No	No	No	No	No	No	No	No
		Tool Marks	No	**Yes (4)**	**Yes (3)**	No	No	No	**Yes (7)**	No	No	No
		Current control	*N/A*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
		Bad Surface Finish		No	No	No	No	No	**Yes (3)**	No	No	No
		Current control	*N/A*	*N/A*	*Yes*	*N/A*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
		Bend / Warpage	**Yes (1)**	No	No	No	No	No	No	No	No	No
		Current control	*No*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

Cause and Effect Di gram for Defect Neck over Size

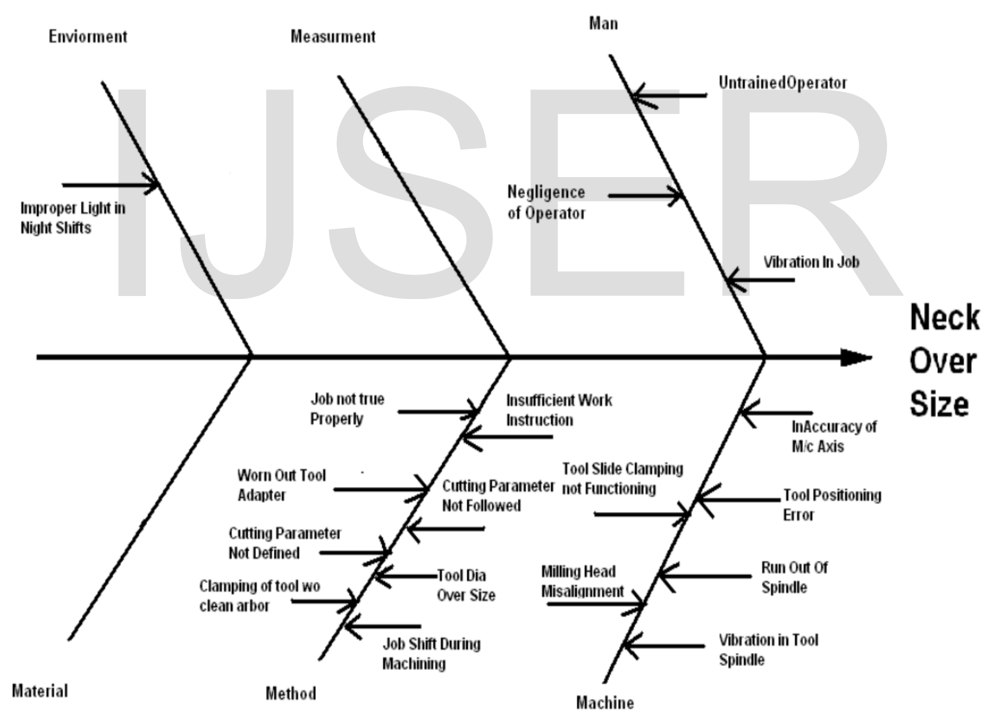

Fig. 5: Cause and Effect Di gram for Defect Neck over Size

Table 6: IOM Analysis for Defect Neck over Size

IOM Analysis for Defect Neck Over Size									
Sr.No.	**Possible Causes**	**Cause**	**Impact**	**Occurrence**	**Mitigation**	**Score**	**Individual %**	**Cumulative**	**Cumulative %**
1	**Untrained Operator**	**C1**	**9**	**9**	**9**	**729**	**15.88**	**729**	**15.88**
2	**Tool**	**C2**	**9**	**9**	**9**	**729**	**15.88**	**1458**	**31.76**

	Positioning Error								
3	Milling Head Misalignment	C3	9	9	9	729	15.88	2187	47.65
4	Negligence of Operator	C4	9	3	9	243	5.29	2430	52.94
5	Vibration in Job	C5	9	3	9	243	5.29	2673	58.23
6	Run Out of Spindle	C6	9	9	3	243	5.29	2916	63.53
7	Insufficient Work Instruction	C7	9	3	9	243	5.29	3159	68.82
8	Tool Slide Clamping not Functioning	C8	9	9	3	243	5.29	3402	74.12
9	Cutting Parameter not defined	C9	9	3	9	243	5.29	3645	79.41
10	Cutting Parameter not followed as instructed	C10	9	3	9	243	5.29	3888	84.7
11	Job not True Properly	C11	9	3	9	243	5.29	4131	90
12	In Accuracy of Machine Movement in X,Y,Z Axis	C12	9	9	1	81	1.76	4212	91.76
13	Vibration in Tool Spindle	C13	9	9	1	81	1.76	4293	93.53
14	Clamping of Tool without cleaning of Arbor	C14	3	3	9	81	1.76	4374	95.29
15	Job Shifting During machining	C15	9	1	9	81	1.76	4455	97.06
16	Tool Dia Over Size	C16	9	1	9	81	1.76	4536	98.82
17	Worn Out or damaged Tool Adapter	C17	9	1	3	27	0.59	4563	99.41
18	Improper Light in Night Shift	C18	3	1	9	27	0.59	4590	100

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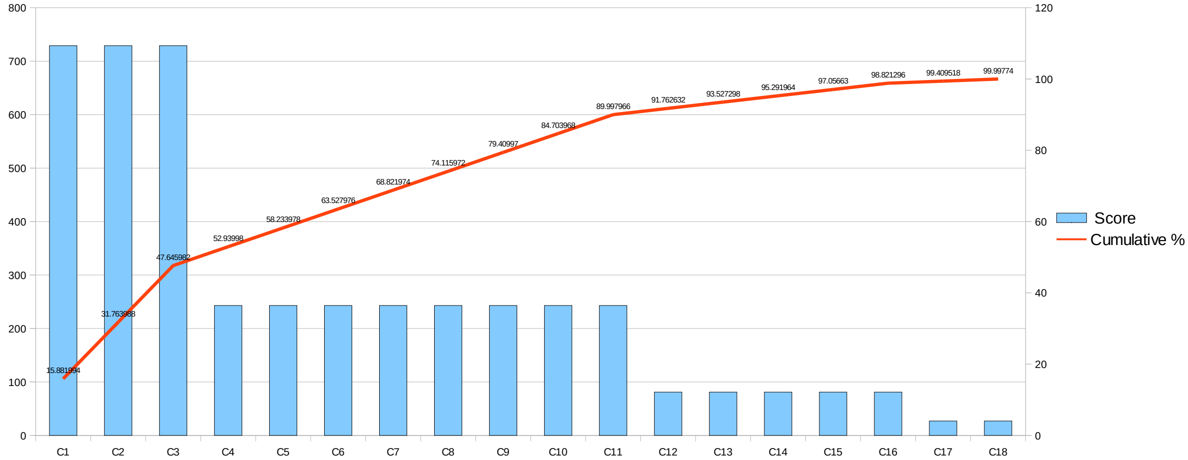

Fig.6: Pareto chart for Defect Neck over Size

Table 7: Why Why Analysis for Neck Over Size

Why-Why Analysis for Neck Over Size

Why1 ?	Why2	Why-3	Why4	Why5	Why6	Action	Responsible
Why Neck Oversize?	Error in Tool Positioning	Positioning done by manual	DRO system out of order	Negligence Towards maintenance	Improper maintenance system	Autonomous, PM & Predictive MAINTENANCE system to be made & adhere	FH
		Shifting of milling head during cutting	Clamping of tool slide not working	Pneumatic power inadequate	pneumatic supply line size less	pneumatic supply line size to be Increased, extra receiver to be installed	FH
				Not repaired due to machine unavailability for maintenance		Maintenance plan (PM, AM & Predictive maintenance) of Machine to be followed	FH
Why Neck Oversize?	Operator Untrained	Due to Shortage of manpower Unskilled operator deployed	Training not provided to operator	No training system		Training system & training schedule to be made according training manual	FH

Why Neck Oversize?	Milling Head Misalignment	Squareness of Milling head not set				Maintenance Dept. instructed to take care of squareness after every removal of Milling Head	FH
Why Neck Oversize?	Vibration in Job	Job not Clamp Properly	Proper clamping element not available			Dedicated clamping element provided on each machine or work center	FH
Why Neck Oversize?	Run Out of Spindle					Dedicated clamping element provided on each machine or work center	FH

7.3 Inventory Control:

After implementation of 5's , finish good stock list was prepared then from that list high value item separated & these items analyzed by ABC analysis which is shown in tables & graph below. Then for its consumption following strategies were made:

Table 8: ABC analysis of the last m onth stock in PSE industry.

INVENTORY

SR. NO.	SIZE	ITEM NAME	QTY	AMOUNT	CUMULATIVE AMOUNT	CUMULATIVE %
1	4500 X 2000 X 350 MM	BED PLATES	2	2163840	2163840	27.07914101
2	1600x1000 MM	SURFACE PLATES	9	1209600	3373440	42.21654903
3	2000x1000 MM	SURFACE PLATES	6	940800	4314240	53.9900886
4	Granite 2000 X 1000 MM	GRANITE PLATE	2	503040	4817280	60.28632813
5	1500X1500	WELDING PLATEN	6	480000	5297280	66.29223607
6	1000x1000 MM	SURFACE PLATES	7	448000	5745280	71.89868349
7	1000X630 MM	SURFACE PLATES	5	312000	6057280	75.80317365
8	Granite 1000X1000 MM	GRANITE PLATE	2	251520	6308800	78.95079341
9	4000 L X 350 H X 90 W MM	STRAIGHT EDGES (I-SEC.)	4	230400	6539200	81.83410923
10	Granite 1000 x 630 MM	GRANITE PLATE	2	160000	6699200	83.83641187
11	350 x 200 x 250 MM	ANGLE PLATE	27	142560	6841760	85.62046353
12	630x630 MM	SURFACE PLATES	6	110400	6952160	87.00205236
13	3000X55X250	STRAIGHT EDGES (I-SEC.)	4	96000	7048160	88.20343395
14	125 x 75 x 100 MM	ANGLE PLATE	40	80000	7128160	89.20468627
15	175 x 100 x 125 MM	ANGLE PLATE	33	66000	7194160	90.03053512
16	450x300x350 MM	BOX ANGLE	4	64000	7258160	90.83145617
17	500 X 500 X 50 MM	SQUARE FRAME	6	48000	7306160	91.43214697
18	450 x 300 x 350 MM	ANGLE PLATE	4	44800	7350960	91.99279171
19	250 x 150 x 175 MM	ANGLE PLATE	14	35840	7386800	92.4413075
20	400 X 275 X 500 MM	TOOLING BLOCKS	1	32000	7418800	92.84176803
21	800X400X800 MM	ANGLE PLATE	1	30720	7449520	93.22621014
22	350x200x250 MM	BOX ANGLE	3	26400	7475920	93.55659008
23	400 X 150 X 500 MM	TOOLING BLOCKS	1	25600	7501520	93.8769585
24	2500 MM	STRAIGHT EDGES (I-SEC.)	2	22400	7523920	94.15728087
25	630 X 400 MM	SURFACE PLATES	2	20800	7544720	94.41758022
26	450x300 MM	SURFACE PLATES	4	20480	7565200	94.67387496
27	300x300 MM	SURFACE PLATES	6	19200	7584400	94.91416127
28	1000 MM	STRAIGHT EDGES (I-SEC.)	6	19200	7603600	95.15442759
29	1600X170X70 MM	STRAIGHT EDGES (I-SEC.)	2	19200	7622800	95.39470391
30	3000X170 MM	STRAIGHT EDGES (I-SEC.)	1	18400	7641200	95.62496871
31	250x250 MM	SURFACE PLATES	8	17920	7659120	95.84922661
32	350X200X250 MM(T-SLOTTED)	BOX ANGLE	2	17600	7676720	96.0694799
33	1600 MM	STRAIGHT EDGES (I-SEC.)	2	17600	7694320	96.28973319
34	1200X800X85 MM	BED PLATES	1	16000	7710320	96.48996346
35	RECTANGULAR FRAME 600X400X50 MM	SQUARE FRAME	2	16000	7726320	96.69019372
36	250x150x175 MM	BOX ANGLE	4	15360	7741680	96.88241478
37	Granite 600 x 400 MM	GRANITE PLATE	2	14400	7756080	97.06262202
38	450X300X350 MM(T-SLOTTED)	ANGLE PLATE	1	14400	7770480	97.24282925
39	2000x50x150 MM	STRAIGHT EDGES (I-SEC.)	1	12800	7783280	97.40301347
40	2000 MM	STRAIGHT EDGES (I-SEC.)	1	12800	7796080	97.56319768
41	300X200 MM	SURFACE PLATES	6	11520	7807600	97.70736347
42	350 x 200 x 250 MM(T-SLOTTED)	ANGLE PLATE	2	11520	7819120	97.85152926
43	Granite 400 x 250 MM	GRANITE PLATE	2	11200	7830320	97.99169044
44	125x75x100 MM	BOX ANGLE	10	11200	7841520	98.13185163
45	400x400 MM	SURFACE PLATES	2	9600	7851120	98.26198979
46	1600X50X150 MM	STRAIGHT EDGES (I-SEC.)	1	9600	7860720	98.37212795
47	175x100x125 MM	BOX ANGLE	7	8960	7869680	98.4842569
48	175 X 100 X 120 MM	ANGLE PLATE	11	8800	7878480	98.59438354
49	1500 L X 160 H X 70 W MM	STRAIGHT EDGES (I-SEC.)	1	8800	7887280	98.70451019
50	825 X 100 X 90 MM	STRAIGHT EDGES (I-SEC.)	1	8000	7895280	98.80462632
51	400X400X75 MM	PALLET SUB TABLE	1	7040	7902320	98.89272664
52	350 X 350 X 250 MM	BOX PARALLELS	3	6720	7909040	98.97682335
53	450x450x50 MM	SQUARE FRAME	1	6400	7915440	99.05691545
54	800 MM	STRAIGHT EDGES (I-SEC.)	4	6400	7921840	99.13700756
55	300X200X125 MM	BOX PARALLELS	2	6080	7927920	99.21309506
56	400x250 MM	SURFACE PLATES	2	5760	7933680	99.28517795
57	250x150x175 MM(T-SLOTTED)	ANGLE PLATE	2	5760	7939440	99.35726085
58	200X200X200 MM	BOX PARALLELS	2	5760	7945200	99.42934375
59	1200 MM	STRAIGHT EDGES (I-SEC.)	1	5600	7950800	99.49942434
60	GRANITE 300 X 300 MM	GRANITE PLATE	1	4800	7955600	99.55949342
61	0.203X0.152X0.406 MM	ANGLE PLATE	2	4160	7959760	99.61155329
62	1000 MM	STRAIGHT EDGES (C.B.)	1	4160	7963920	99.66361316
63	Granite 250 x 250 MM	GRANITE PLATE	1	4000	7967920	99.71367072
64	750 MM	STRAIGHT EDGES (C.B.)	1	4000	7971920	99.76372829
65	300X250X150 MM	SWIVEL ANGLE PLATE	1	2400	7974320	99.79376283
66	250x150x175 MM	UNIVERSAL ANGLE PLATE	1	2400	7976720	99.82379737
67	300x300x50 mm (MACHINE CHECKING SQ.FRAME)	SQUARE FRAME	1	2400	7979120	99.85383191
68	150 x 150 x 100 MM	BOX PARALLELS	2	2240	7981360	99.88186414
69	250 X 250 X 250 MM	ANGLE PLATE	1	1920	7983280	99.90589178
70	600 MM	STRAIGHT EDGES (I-SEC.)	1	1920	7985200	99.92991941
71	500 MM	STRAIGHT EDGES (I-SEC.)	2	1600	7986800	99.94994243
72	750 MM	STRAIGHT EDGES (I-SEC.)	1	1600	7988400	99.96996546
73	150 x 150 x 150 MM	ANGLE PLATE	1	1280	7989680	99.98598388
74	150X150X150 MM	BOX PARALLELS	1	1120	7990800	100

- Order of high value items are authorized only by the departmental head after cautions study of the consumption figure.
- Estimate the schedule of stock verification e.g. high price item checked more frequently then low price item.
- To give the target to sale of high value item to marketing department.
- Involve buying strategies to control purchase e.g. excess supply than the order quantity may not be accepted for high value items.
- Inventory control section should be very cautions in purchase of those items in the future.

Table 9: High value item selection

HIGH VALUE ITEM SELECTION

SR. NO.	SIZE	ITEM NAME	WEIGHT	QTY	AMOUNT	CUMULATIVE AMOUNT IN DECENDING ORDER	CUMULATIVE %
1	4500 X 2000 X 350 MM	BED PLATES (4.5X2.0X.35)	7728	2	2163840	2163840	27.07914101
2	1600x1000 MM	SURFACE PLATES (1.6X1.0)	840	9	1209600	3373440	42.21654903
3	2000x1000 MM	SURFACE PLATES (2.0X1.0)	980	6	940800	4314240	53.9900886
4	Granite 2000 X 1000 MM	GRANITE PLATE (2.0X1.0)	1572	2	503040	4817280	60.28532813
5	1500X1500	WELDING PLATEN (1.5X1.5)	500	6	480000	5297280	66.29223607
6	1000x1000 MM	SURFACE PLATES (1.0X1.0)	400	7	448000	5745280	71.89868349
7	1000X630 MM	SURFACE PLATES (1.0X0.63)	390	5	312000	6057280	75.80317365
8	Granite 1000X1000 MM	GRANITE PLATE (1.0X1.0)	786	2	251520	6308800	78.95079341
9	4000 L X 350 H X 90 W MM	STRAIGHT EDGES (I-SEC.) (4 L)	360	4	230400	6539200	81.83410923
10	Granite 1000 x 630 MM	GRANITE PLATE (1.0X0.63)	500	2	160000	6699200	83.83641187
11	350 x 200 x 250 MM	ANGLE PLATE (0.35X0.20X0.25)	33	27	142560	6841760	85.62046353
12	630x630 MM	SURFACE PLATES (0.63X0.63)	115	6	110400	6952160	87.00205236
13	3000X55X250	STRAIGHT EDGES (I-SEC.) (3 L)	150	4	96000	7048160	88.20343395
14	125 x 75 x 100 MM	ANGLE PLATE (0.125X0.075X0.10)	5	40	80000	7128160	89.20458527
15	175 x 100 x 125 MM	ANGLE PLATE (0.175X0.10X0.125)	5	33	66000	7194160	90.03053512
16	450x300x350 MM	BOX ANGLE (0.45X0.30X0.35)	100	4	64000	7258160	90.83145617

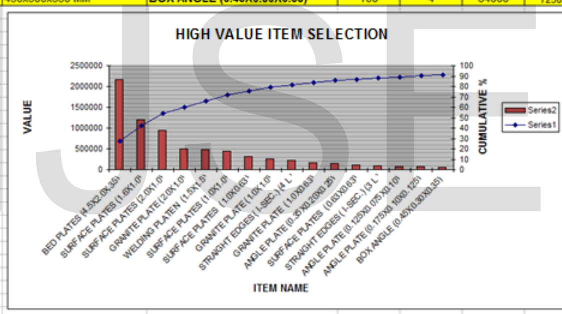

Fig.7: Graph for High value item selection

8. Recommended Suggestions to Apply Lean Manufacturing in PSE Industry

In order to reduce the waste and improve the productivity by application of lean manufacturing the following main opportunities were identified.

1. Waiting Time: It has been seen that in a shop floor waiting occur due to there is only one crane to shift material one machine to another machine during operation. It can be avoided by installing of one more crane in shop floor

2. Over processing: In a company there is a scraping department where product comes after machining for maintaining geometrical accuracy (flatness, squareness, parallity,) which is not achieved after machining, for which over processing has to be done to maintain geometrical accuracy by hand scrapping because which it took more time, so to reduce over processing we can recondition & proper Total predictive maintenance of the machines & there are three CNC machine which are old and not used regular so we can sell to CNC machine and buy new machine by which can reduce the time taken for hand scraping

3. Excess Inventory: excess inventory of finish goods are stored which is hold the huge cost. According to last data finished goo of about 10 lacks are still stored which is not sold from 5-7 years due to old design. That material can be scrapped & sell it or can be recycling it and can be make new product. By reducing manufacturing lead time, it will automatically reduce unnecessary finish goods inventory. Reduction in overall inventory will generate very significant additional cash flow savings for the organization.

4. Excess motion: here movement of workers is high because in their work place proper tools & working instrument are not available at time. To reduce this excess motion of worker we can take following step:

- Before starting the job process sheet should be displayed.
- Standard operating cutting parameters for every operation should display in each work station.
- Individually Tool kit should be provided in each work station individually.
- Individual measuring instrument should be provided in each work station.
- Operator Auditing should be done in every 15 days for checking tool kit and measuring instrument.

The above parameters also increase productivity of labor And also improve setup time of job.

5. Defects: Reduce quality inspector Inspection Time. Get in-process inspection reports from operator by verification of line supervisor. Need operation wise in-process inspection reports from operator. Get 100% parameter verify by line supervisor during operation at every stage.

Some other recommendations provided to eliminate wastages are, proper production planning, effective application of industrial engineering, well trained operator, proper layout plan, minimum rework, proper line balancing, right time oiling to the machineries, ensuring quality production, sufficient numbers of working aids can be provided for smooth working. These recommendations were suggested to the shop floor in the PSE industry.

8. CONCLUSION

In the paper, Lean concepts have been successfully implemented in the manufacturing PSE industry. 5 S's implementation can be a valuable tool for developing and implementing lean improvement projects. By applying lean concepts, the elimination of wastages are reduced up-to 50%.Now the future state lean manufacturing becomes current state lean, in that still more new developments and improvements can be added to reduce lead time and achieve lean, this process is repeated until an ideal state is established. The process of creating the 5 S's implementation was helped and trained to all the shop floor team members on lean techniques and to reveal the opportunities on reducing waste. Lean concepts can also be implementing to other products in the manufacturing company, so that we can reduce the delivery lead time for all the products.

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