Implementation Study on Applying Lean Manufacturing Principles in the Manufacturing of Pressure Vessels in an Indian Company

Ben Ruben R, Narendran S A P, Syath Abuthakeer, Prasanth A S, and Mohanram P V

Abstract**—**This paper presents a work undertaken in a pressure vessel manufacturing company which produces different models of pressure vessels which are used for manufacturing of air compressors. The work aim was to improve the productivity solving several problems encountered in the production system, such as: long lead times, unnecessary motions, too many material handling, dead inventory and a non standardized working environment. The identified problems were analyzed and improvement actions were scheduled and subsequently implemented. These improvement actions were based on Lean production organizational model and application of Lean tools. The 5S methodology was implemented in the workplace as well as standardized operating procedures, and layout reconfiguration was done to the existing system. These actions led to a reduction of the operating cycle time, work in progress, transports, delivery delays, and created an well organized working environment.

Keywords**—**Lean production system, wastes, full welding, child parts assembly standardized operating procedure, Case study.

I. Introduction

LEAN production is a is a well established organizational model implemented in companies throughout the world. "Lean" is the word that had been used to refer Toyota Production System .Lean manufacturing is focused on eliminating waste in the entire manufacturing process. It deals with minimizing work-in-process, eliminating processes that do not add value to the product, making the process flexible to make products of different design without compromising quality or cost. Lean philosophy is universal and can be applied to manufacturing, design, quality control, administration, order taking, accounts receivable or any activity that needs to be improved**.** TPS considered seven "deadly" kind of wastes: overproduction, unnecessary motion, unnecessary transport and handling, defects, inventories, waiting, over processing, and lean methodology focuses on eliminating these wastes .

The key lean principles includes the following:

- Perfect first time quality
- Waste minimization by removing all non value adding activities
- Continuous improvements
- Establishing pull system
- Flexibility in production.

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Eliminating such wastes and putting inaction the principles referred requires diverse tools like Value Stream Mapping, 5s, pull system, standard operating procedures, and mistake proofing etc. This paper presents the implementation of Lean manufacturing principles in an Indian pressure vessel manufacturing company which is located in the city of Coimbatore, in the state of Tamil Nadu. This paper represents the work done in the company to find out the bottle neck operation and to improve the productivity of those stations by applying lean principles and to escalate the dead inventory. Initially time study was conducted at every stations and video study was performed for waste capturing. Later the layout was reconfigured to suite the production and 5s was implemented to create a better organized work place. The main objective was to decrease the operating cycle time

II. Literature Survey

J. Womack et al [1] discussed briefly about the lean methodology and the various key principles that must be adopted to establish a lean environment. Y. Monden et al, [2] discussed about the Toyota production system and the various tools and techniques which they applied to their organisation. M. Holweg[3] proposed a model that followed the one piece flow principle and the changes that are to be adopted to achieve it. D. Jones et al, [4] proposed the concepts of lean thinking and also they framed a model for achieving the lean production system. M. Imai[5] discussed about the kaizen approaches that are adopted in the production line that aims for continuous improvements in both the process and the system. It also empathised the formation of a cross functional team in arriving better results. This is the sequel to the author's earlier successful book, Kaizen. It also summarizes and extends much of the earlier work with examples and case studies. "Gemba Kaizen" means continuous improvement in the workplace. J. Liker[6] discussed about the 14 management principles which was followed by Toyota and also explained about the need for practicing the mentioned principles.] M. Rother[7] et al, provided the usage of 5s and value stream mapping to identify the value adding and non value adding activities and also about the ways prescribed to eliminate the typical wastes. The Productivity Press Development Team [8] proposed a standard operating procedure that has to be followed in the shop floor to eliminate the unnecessary motions and other waiting activities. K. Suzaki[9] proposed a model which motivates the firm to achieve continuous improvements by using the lean tools and also the importance of forming a cross functional team. M. L. Spearman et al [10] proposed an integrated model to achieve pull system by consistent elimination of wastes. Emiliani, B et

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al,[11] framed a model that suits the business environment for practicing the lean principles and also provided a framework for business process reengineering. Kobayashi, I et al,[12] highlights 20 different skills in a broad perspective that can be used to make the lean manufacturing journey possible. It also contains an evaluation system that helps pinpoint facets where improvements are needed.

The literatures provided wide information about the lean manufacturing principles and its applications at various business enterprises. The information gathered from the papers was very useful in analysing the current production system and also gave useful information about the modifications that must be made to the processes to achieve flow by consistent elimination of wastes.

III. Case Study

The selected pressure vessel manufacturing company is the leading manufacturer of pressure vessels in India and one of largest manufacturer of air compressors in Asia.. The company was established in 1960 at Coimbatore, the number of people working in the company is nearly 2000. It is an ISO 14001: 4000 certified company and also holds a BS OHSAS 18001:2007 certification. This company manufactures around 40 different varieties of pressure vessels. There are three basic models of pressure vessels namely 220L, 160L AND 500L. The pressure vessels are broadly classified into two different categories. They are RCD models (reciprocating compressor division) and ROCD (rotary compressor division) models. The manufactured pressure vessels are fitted with the air compressors and the main task of the pressure vessels is to separate the air and oil in the incoming mixture in the compressors.

A. Assembly sequence of the pressure vessel

The assembly sequence of the pressure vessel consists of fifteen different operations. The first operation is the plasma arc cutting where the sheet metal is being cut into the desired size. The next operation is the edge beveling operation where the edge surface marks and projections are being removed. It is followed by the rolling operation where the sheet metal is being rolled and the rolled sheet metal is called as the shell.

The next operation is the long seam welding followed by the disc-tac fit up assembly, where the dish and shell are welded together. The next operation is the circular seam welding where the initial spot welding in made into a continuous weld. The next station is the child parts assembly where some sub-assembled parts are being welded to the vessel. It is followed by the full welding operation in which all the spot welded areas are welded as a stitch weld or full weld.

The next station is the hydro leak test where the tank is filled with pressurized water to check if there are any leakages in the tank. It is followed by the shot blasting process and followed by powder coating process. The final station is the packing despatch and inspection.

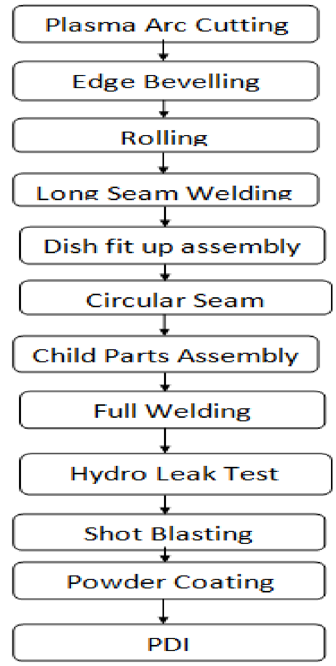

Fig. 1 Flow chart of pressure vessel assembly

B. Identification of Bottle neck operation

Initially time study was performed at every station to find out the cycle time. Time study was performed for both the RCD and ROCD models. Based on the data obtained from the time study process, it was found that the full welding process and child parts assembly were found to be the bottleneck process.

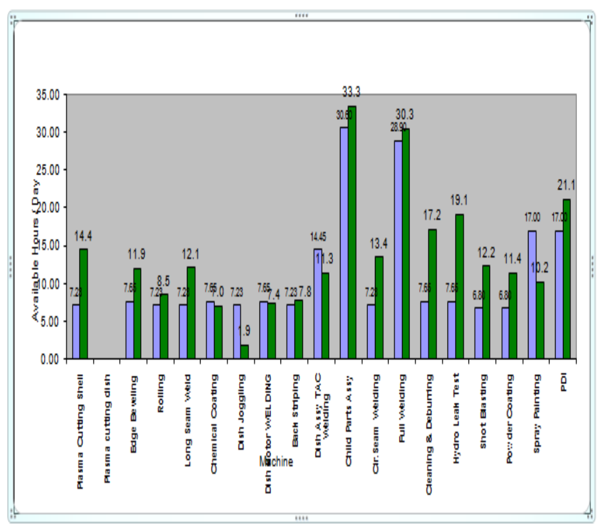

Fig. 2 Flow chart of operating cycle time vs available time

The net available time per shift is 510 minutes, and the company plans for second shift if the target is not met .But the ultimate aim of firm is to complete the process within the first shift. Now after identifying the bottle neck operation, various studies and analysis were done to minimize the bottle neck.

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iii. Full welding process improvement

A. Full welding process

In full welding process the vessel is loaded in the fixture with the help of trolley. The tank is carried from the finishing point of child parts assembly to the station by the trolley where the operator performs the task of loading and unloading. Once the loading gets over, the operator performs the pre welding requirements like stritch marking with chalk, oil spraying and cleaning the torch. After performing these tasks, the operator wears the face mask, gloves and other safety gadgets

Now the operator starts the welding operation and welding time and procedure changes from tank to tank.

Totally the whole operation consists of task like loading, operation, unloading and time units like operation time, machining time, movement time loading and unloading time.

B. Waste capturing in Full welding process

For capturing the waste, video study was performed to record the process and to analyse the procedures and the practices which the operator performs during the full welding process. Video study was performed for four basic types of tanks namely 220 litres, 160 litres, 500 litres and 637 models. The process changes from tank to tank and finally waste was captured by viewing the video. The wastes were classified according to the lean methodology and were made to fit under the lean wastes. The typical wastes that were observed were categorized into transportation, motion, waiting and defects. After performing the video study the total time was categorized into operation time, machining time, waiting time, loading and unloading time operation time and machining time falls under the value adding time category and waiting time ,loading and unloading time falls under the non value adding time category.

220-FULL WELDING PROCESS

Total welding time = 54.23

Operation time = 10.36

Machining time = 34.42

Movement time = 04.11

Loading and unloading time = 04.54

500-FULL WELDING PROCESS

Total welding time = 48.12

Operation time = 16.39

Machining time = 27.41

Movement time = 01.36

Loading and unloading time = 02.16

*all units are in minutes

C. Classification of wastes

TRANSPORTATION

a. moving the trolley to the child parts location point
b. moving t he trolley to the position and come back
c. bringing the trolley to the station
d. lifting the trolley
e. lifting t he tank with the trolley
f. moving the trolley with tank to drop position

MOTION

a. Loading the tank in the trolley and move it to the welding station
b. Picking up the stitch marking scale and oil spray
c. To pick the chalk
d. To pick the spirit level
e. Move for picking up the drain plug

WAITING

a. attaching mandrel to the tank
b. communicating with worker at next station
c. cleaning the torch
d. spraying the torch
e .removing the mandrels

C. Improvement action plan

WHAT?	WHY?	WHO?	HOW?
IMPLEMENT 5S	FREQUENT MOTIONS IN BETWEEN THEOPERATION IN SEARCH OF TOOLS AND GADGETS	PLANNING DEPARTMENT	DISCUSSION ABOUT 5S AND CREATION OF AN IMPLEMENTATIO N PLAN
DECREASE THE TOTAL CYCLE TIME	IN CURRENT SCENARIO MORE TIME IS SPENT ON LOADING AND UNLOADING	PRODUCTION AND PLANNING	SUGGESTED ALTERNATIVE IMPROVEMENTS FOR LOADING AND UNLOADING(ONE PIECE FLOW)
PROPOSE AN ALTERNATIVE LAYOUT	HIGH TRANSPORT OF MATERIAL INBETWEEN THE SECTIONS	PRODUCTION AND PLANNING	ANALYSING MOVEMENT IN BETWEEN THE SECTIONS
DESIGN OF A MODULAR FIXTURE	FOR EASY LOADING AND UNLOADING	DESIGN DEPARTMENT	ADAPTING THE TECHNIQUES OF POKAYOKE AND SMED
ADDITION OF ONE OPERATOR	FOR LOADING,UNLO DING, STRITCH MARKING	PRODUCTION AND PLANNING	BY PERFORMING OPERATOR BALANCING

Fig. 3 Improvement action plan

After classifying the waste, an action plan was created to minimize the wastes in the work place. The main aim of the action plan was to create an orderly work place which minimizes the wastes like transportation, waiting and unnecessary motion.

C. Operations that can be eliminated

After analyzing the video study, there was a lot of scope for improvement subjected to some changes in the existing system. The proposed new model eliminated few operations that were currently performed. Some of the operations that can be eliminated are,

- moving the trolley to the child parts location point
- moving the trolley to the position and come back
- bringing the trolley to the station
- lifting the trolley
- lifting the tank with the trolley
- moving the trolley with tank to drop position
- loading the tank in the trolley and move it to the welding station
- Picking stitch marking scale and oil spray
- picking the chalk
- picking the spirit level
- attaching mandrel to the tank
- communicating with worker at next station
- cleaning the torch
- spraying the torch
- removing the mandrels
- clamp the mandrel with the fixture
- spraying the tank with oil
- picking up the chalk
- marking with chalk on the tank

C. Implementing the new model

The first step which was taken was to implement the 5S methodology.5S was implemented considering only the full welding workstation .All the unwanted materials were removed and dead inventory escalation was performed to create an ordered work place. As a part of the action plan a kit was provided at each workstation which included a spirit level, spanner, spraying oil, marker, scale and other welding accessories. Providing the kit, eliminated the unnecessary motions in between the operation and also to eliminate the time spent on searching the tools. A modular fixture was designed and manufactured. This fixture has the capability of holding all models of tanks and a pneumatic system was installed for automatic clamping. This modular fixture was designed based on the concept of SMED and the operation of loading and unloading was made easy so that less effort was applied by the worker.

The next task was to appoint an additional worker in the full welding station. To justify the need of an additional worker the tasks that has to be performed by the worker was clearly defined. The tasks included carrying the vessel from the child parts assembly station to the full welding station and to perform the tasks like spraying, marking, loading unloading so that the only role of the operator is to perform the welding operation .In the previous case entire work stating from loading, spraying, marking and unloading was done by the operator himself. Since there are three full welding stations a proper work balance chart was framed and the job to the new worker was perfectly balanced.

D. Results after successful implementation

After successfully implementing the above mentioned factors, the operating cycle time of the full welding process was considerably reduced. The welding time for the model 500litres was reduced to 36 minutes from 48 minutes, and the time for 220 model was reduced to 40 minutes from 54 minutes and 637 model's cycle time was reduced to 30 minutes from 35 minutes(since the size of the tank is small less time is spent on loading and unloading)

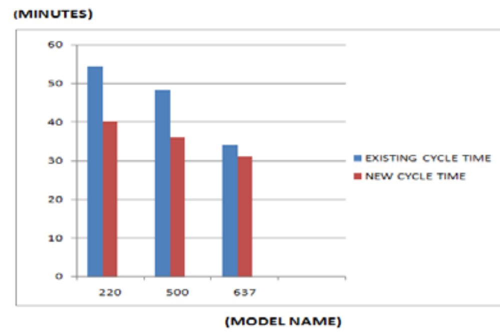

Fig. 4 Existing cycle time versus new cycle time of full welding process

iii. Child parts assembly improvement

A. Child parts assembly process

Child parts assembly is a process where the sub assemblies are fitted to the pressure vessel. The sub assemblies includes the sockets (size varies from model to model), motor beds, unit beds, belt guards, air-o-pipes, flanges and connecting pipes. In the current system the sub assemblies are arranged together in storage points and it is very difficult for the operator to classify the sub assemblies and more time is spent on unnecessary motions and searching the sub assemblies. Both the RCD and ROCD models are assembled at the same work station and more time is spent on separating the sub assemblies that are not common for RCD and ROCD models.

B .Child parts assembly process improvement

In the current system, the sub assembled parts are welded to the pressure vessel in the child parts assembly area and this area is common for both reciprocating compressor division (RCD) and rotary compressor (ROCD) division models All the sub assembled parts are stored in the same area and it becomes a difficult job for the operator to classify the RCD and ROCD sub assembled parts. And also the workers did not follow any standard operating procedure and there was an increase in cycle time even though the process can be completed in a less span of time.

First step for process improvement was to reconfigure the current layout. In the present layout there is a common child parts assembly area were both the RCD and ROCD models were assembled. The modified layout proposed a new concept were two child parts assembly areas were used and each one serving exclusively for their models (one for RCD and other one for ROCD). The new layout eliminated the unwanted transportation in between the stations and also the waiting time was reduced.5S was also implemented in the stations such that separate space was for allocated to store the sub assembled parts and racks for holding the tools was also provided. The layout facilitates flow and also makes the working environment more comfortable.

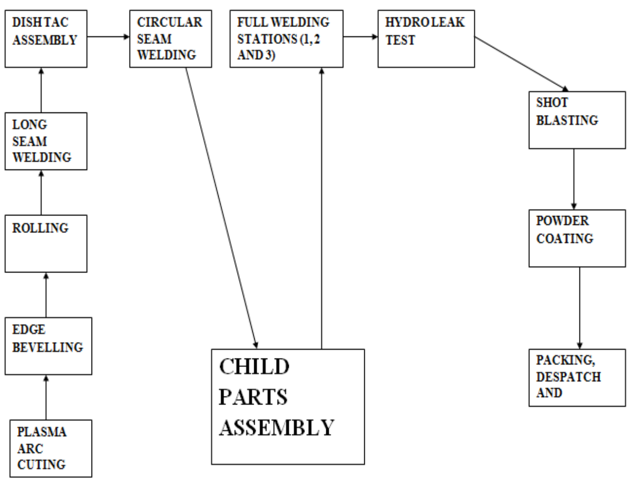

Fig. 5 Current layout of the pressure vessel division

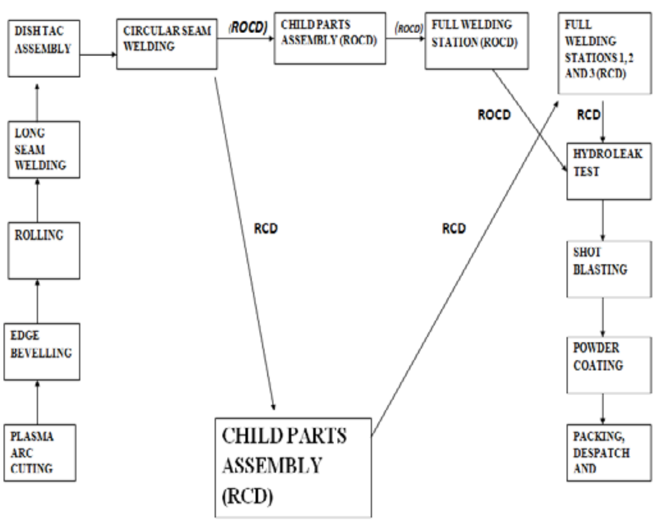

Fig. 6 Modified layout of the pressure vessel division

D. Results after successful implementation

In the earlier layout, the per day output of the child parts assembly area was 30 tanks which included 20 RCD models and 10 ROCD models. After modifying the layout and successful implementation of 5S concepts the per day output was increased to 42 tanks which included 25 RCD models and 17 ROCD models.

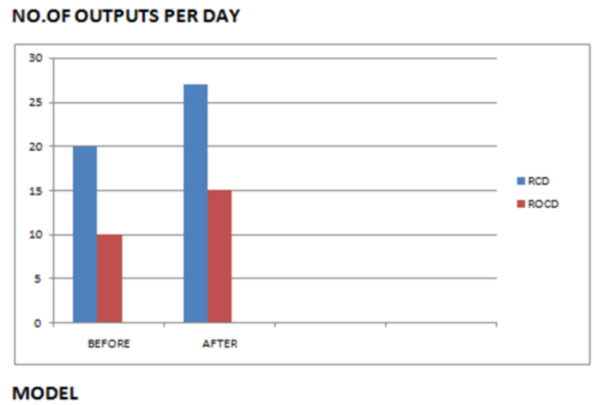

Fig. 7 Outputs produced per day in child parts assembly station

IV. Results and Discussion

After the successful implementation of the above concepts and application, the bottleneck stations i.e. full welding and child parts assemblies total operating cycle time was reduced and also its productivity was improved considerably .An well organized workplace was achieved by applying the 5S methodology and also the process of dead inventory escalation was performed successfully. It helped the firm to increase the percentage of its adherence level of plan and also it was able to manufacture and deliver the pressure vessel within the mentioned time and minimized the chances of lateness. At the investment point of view, the firm had to invest in buying the modular fixture and also for the kits that was provided at each stations.

FACTORS	BEFORE IMPLEMENTATION	AFTER IMPLEMENTING
Full welding station productivity	27 vessels	45 vessels
Child parts assembly productivity	30 vessels	42 vessels
Holding the vessel during welding	Generalised fixture which consumed more time on loading and unloading	Modular fixture is used
5s practices	Not followed	Successfully implemented in two stations
Dead inventory	Remained in the shop floor	Completely escalated
Storing tools and other welding accessories	No separate place was there and more time was spent on searching	Kit was provided at each station
layout	Older layout had more unnecessary transportation and motions	Reconfigured layout Minimized the unnecessary motions
Per day output	Achieved was less than the planned	Adherence level to plan was increased

Fig. 8 Results achieved before and after implementation

V. Conclusion

In this project steps were taken to improve the productivity of the pressure vessel manufacturing unit by creating a better organized system by implementing 5s which reduced the motions and waits and also provided a better working environment. Dead inventory escalation was also performed as a part of 5s to remove the scrap and other unnecessary raw materials .An additional worker was employed at the full welding station to perform the pre weld jobs, to reduce the unnecessary waiting. All the wastes were identified and classified according to the lean methodology and appropriate tools were used to eliminate them.

The layout reconfiguration reduced the transport time and promoted the continuous flow. The generalized fixture was replaced by a modular fixture which reduced the time spent on indexing and clamping. Work standards were defined to improve the efficiency of the manufacturing process by creating a standard operating procedure .All these implementations led to the increase in productivity of full welding process and child parts assembly station and also decreased its total operating cycle time.

REFERENCES

[1] J. Womack, D .Jones, D. Roos, The machine that changed the world, Rawson Associates, 1990.

[2] Y. Monden, Toyota Production System - an integrated approach to just-in-time. 3rd Edition, Engineering and Management Press, Institute of Industrial Engineers, 1998

[3] M. Holweg, The genealogy of Lean Production. J. of Operations Management, 2007. 25, p. 420-437. http://dx.doi.org/10.1016/j.jom.2006.04.001

[4] J. Womack, D. Jones, Lean Thinking, Siman & Schuster, USA., 1996.

[5] M. Imai, KAIZEN - the key to Japan´s Competitive Success, McGraw-Hill/Irwin, 1986

[6] J. Liker, The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer, McGraw –Hill, 2004.

[7] M. Rother, J. Shook, J. Womack, and D. Jones, Learning to see: Value Stream Mapping to add value and eliminate MUDA, Lean Enterprise Institute, 1999.

[8] The Productivity Press Development Team, Standard Work for the Shop-floor. Productivity Press; New York, 2002.

[9] K. Suzaki, The New Shop Floor Management: empowering people for continuous improvement. Free Press, New York, 1993.

[10] M. L. Spearman, D. L. Woodruff, and W. J. Hopp, CONWIP: a pull alternative to Kanban, International Journal of Production Research, vol. 28, n. 5, pp. 879-894, 1990. http://dx.doi.org/10.1080/00207549008942761

[11] Emiliani, B., Stec, D., Grasso, L., Stodder, D., Better Thinking, Better Results, The Center for Lean Business Management, Kensington, CT, 2003

[12] Kobayashi, I., 20 Keys to Workplace Improvement Revised Edition; Productivity Press, New York, NY, 1995.

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