Productivity Enhancement In A Pressure Vessel Manufacturing Industry Using Lean Principles

Jiby Johny, M.Thenarasu

Abstract: ***In the competitive market of production, the organizations might want to deliver their merchandise at discounted cost and good quality. During the manufacturing processes, the organization faces several issues during the production of their merchandises. Organizations are in quest for new innovation or strategies to improve their merchandises in ways which take minimum lead time. Numerous specialists/researchers have examined the advancement of manufacturing framework of organizations through continuous upgrade in there standardized format. Lean Techniques like kaizen, kanban, single moment trade of passes on (SMED), Poke-burden, and so on are actualized in the manufacturing framework however the impact of these strategies is acknowledged in production unit simply after numerous years. It is typically targeted to presenting new innovation, new techniques or methods, or a totally new manufacturing framework. The fundamental target of this work manages execution of lean manufacturing principles in the cylinder manufacturing industry so as to improve the efficiency and quality of pressure vessel manufactured without bringing about much expense. Because of production line stoppages and longer lead time of the item, the primary test faced by the organization was not ready to fulfill the customer needs in ideal time. The organization encounters production line stoppages due to improper maintenance of machines and material handling equipment. The major issues faced by industry are because of unstructured method for the stock management, the time between submitting the request and getting completed item from the organization in 29 days, which was of more lead time essentially impacting the stoppage during the production process. Kanban system is implemented in industry as cards and placed. Work in progress Inventory was reduced by 347 units. Current, ideal and future state map was created by collecting the required data. Non-value added activities where highlighted and necessary/practical steps where undertaken to reduce the same. Work-in-progress inventory level was reduced by using kanban control system. Work load has been balanced through automation as per requirement at different stages. Finally by implementing 6s system a new work structure was formed, which gave a path for green manufacturing.***

Index Terms: Value stream mapping, Lean manufacturing, Kaizen, 6s, Superstore, Kanban

I. INTRODUCTION

Now days, every industry strives to implement lean strategies without incurring much cost in investment. Similarly in this project, a case-study on lean implementation was carried on a gas cylinder manufacturing company. Among the different lean tools, Value stream mapping, 6s, kaizen (continuous improvement) were chosen to carry out the implementation of lean in this particular industry. As there should be no negotiation in quality of the gas cylinder, many tests and inspections are done in different stages of production line during its production. So a detailed study of each machine was needed so as to know the problems faced by the operators.Using lean techniques, one can identify different wastes related to processes during production of the product, find the cause and try to eliminate it. Cell modification will give effective utilization of man and machine, thus reducing the unnecessary movement of the worker.

Once the order is placed by the customer, the particular industry starts to make the necessary arrangements in different machines according to the specification of the cylinder. This leads to increase in changeover time, which was considered mandatory by the industry.

In this project, automation model was checked by implementing them between different stations to know how much waiting time can be reduced. Due to automation workers required were also minimized.

Kanban control system was implemented between each process which reduced the work in process inventory.

The 6s lean tool i.e. including safety, were taught to the workers and then a standardized working environment was created.

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II. LITERATURE REVIEW

Shah et. al. [1] has expressed that effective usage of Lean strategies like kanban, continuous flow, Toyota production framework to small scale businesses to enhance man, machine, technique and condition. Their exploration additionally proposes that to utilize VSM through layout would be effective for knowing the non value included exercises driving towards additional stock. Nallusamy et. al. [2] has announced that manufacturing time and in addition value and non value included exercises were recognized through value stream mapping(VSM) and 5-s, line adjusting lean devices and arena simulation was utilized for an effective decrease of process cycle time by proposing another layout for the organization. Nagare et. al. [3] has noticed that process duration and holding up time of the manufacturing firm was effectively decreased and the procedure was made smooth by 5S, SMED and cell manufacturing lean apparatuses. Chan et. al. [4] has noted that there was successful implementation of line balancing and work layout which gave a reduced WIP, cycle time, after that work standardization as a proposal towards kaizen. Sabaghi et. al. [5] has reported that after VSM check, WIP was

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perceived as the most potential opportunity for development and it was effectively investigated through the proposed lean enhancement devices like kanban and TPM. Álvarez et. al. [6] has noted that successful implementation of lean in footwear manufacturing company was carried out by reducing inventory level and cycle time of the product via vsm, kanban. diah et. al. [7] has referenced that the real main root cause of recognized wastes after VSM check were less conscientiously operator, less focus operator, absence of skilled workers, the breakdown of machine, delay of delivery from suppliers of raw materials, and awkward/unclean workplace which have been effectively diminished by 5s, tpm lean tools. Rekha et. al. [8] has reported that in an assembling line of water pump pipe, process duration, lead time and unnecessary movement of laborers were decreased by lean tools like 5s, line adjusting and vsm. Manikanda et. al. [9] has noticed that 5s, line balancing was done to adequately utilize the labours working in the manufacturing line and to increase their efficiency. Project work evacuates a few types of waste that was available in the present system like holding up time, non-used ability, transportation, stock and movement. Saboo et. al. [10] has referenced that effective utilization of the lean manufacturing VSM approach was done to lessen the production lead time, stock, changeover time and all the process activities were improved by considering client request (i.e. takt time) of an Indian assembling SME. Saleeshya et. al. [11] has reported that the score of radar graph of textile industry was expanded after the proposals were made in the field of visual control, 5s housekeeping, poka yoke, standard work, changeover and balancing the production. Also, they recommended that the six sigma can be utilized in the textile business to get six sigma quality items. Saleeshya et. al. [12] states the effective lean usage in a surgical equipment manufacturing, where non value included exercises was highlighted by utilizing value stream mapping and six sigma model was proposed to enhance the profitability of industry. Lead time was likewise diminished by building up a model in relation between batch size and workforce. Khandelwal et. al. [13] states the effective execution of 5s approach for diminishing the vitality devoured by workforce to do a specific action. Therefore enhancing the profitability by supporting the morale of workers. Vignesh et. al. [14] states distinctive factors responsible for lean usage in super market by interpretive structural modeling approach. Top management was considered as the principle factor which was directly involved with lean exercises. Krishnaswamy et. al. [15] The exhibition of AHP-based priority rule was observed to be very huge in limiting the performance measures, for example, lead-time, WIP, machine usage and machine queue related measures. The lead time for handling every one of the parts was accomplished as 23.5 days in press shop from 27 days. The simulation model proposed in the examination was likewise helpful to conduct 'what if?' type investigation in the shop floor. Anbuudayasankar et. al. [16] notified eight models were arranged and simulated using arena. The outcomes support the proposed model without priority rule. As single piece stream help to keep up mess free shop floor and priority rule increments the activity hold up time at shot blasting and heat treatment station. This in the long run motivates shop floor administrator to go with flow metrics in structuring the layout and machine capacity with regards to optimized use. Neeraj et. Al. [17] states because of the automatization of the casting and spraying process, there was increment in profitability by 6% and diminished the workforce by 8.33% and thus expanding the benefit to the organization. The layout design was said to modify, with the end goal that every procedures happen under a solitary assembling unit and avoiding the transportation time and the labor required.

III. CASE STUDY

The case study was conducted in a pressure vessel manufacturing industry established in Kutch district of Gujarat. In this particular firm, different types of pressure vessel cylinders like CNG, Scuba Diving, Fire Fighting, Medical as well as Industrial gases for storage is manufactured. CNG cylinders manufactured for Onboard application is in the range of 20 liter to 160. As the demand for 30 Liters cylinder is more compared to others, the product chosen for creating the value stream mapping is a 267mm diameter, 6mm thickness and water capacity of 30 liter CNG cylinder. The below figure 1 contains image of the selected product.

Figure 1: Product chosen

A. *Material Flow*

The figure 2 shows the flow of material from raw material stage to finished product stage. Between each station regular testing and inspection is carried on so that if defective products are detected, they should not reach next station and send them to according rework station.

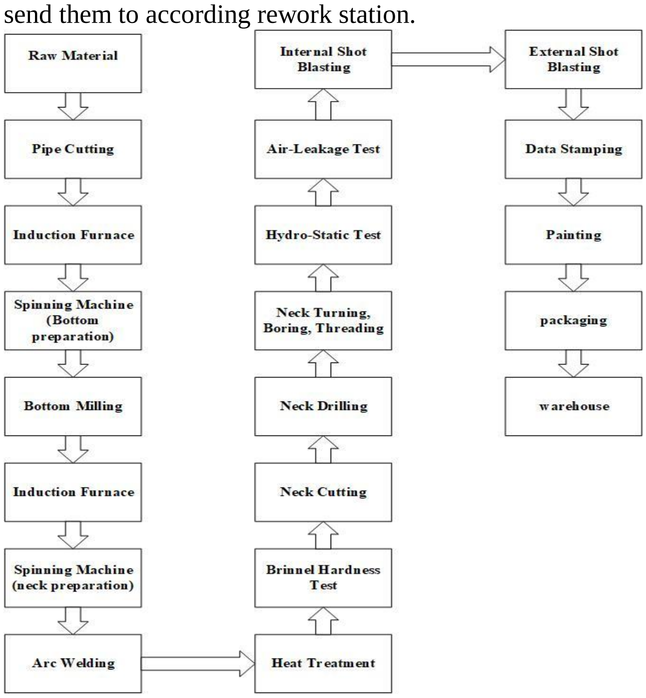


Figure 2: Material Flow

IV. ANALYSIS

The CNG cylinder size of ϕ 267.0 mm, 6.0 mm thickness and 30 liter water capacity was selected for building the map as it had highest demand among all the other specifications of CNG cylinders.

Customer demand: 7500 cylinder pieces/month. Management policy is to produce 492 pieces extra as safety stock.

The data like Machine cycle time, set-up time, workforce, batch size and number of inventories between each station where collected using stop watch, visual inspection and reported to the manager and production in charge to build a current, ideal and future state map. Movements of workers of downstream operations were recorded by calculating the number of steps taken to reach the store.

After collection of the required data, Visio’13 Software was used to create Value stream maps and Plant modification layout for implementing superstore. As the VSM image contains more data, these data was converted into tabular format for better understanding. Each machine is represented in alphabetical order from A to R. WIP inventory indicates the unfinished cylinders ready to go into a particular machine.

After every days production i.e. including two shifts, two cylinders were blasted while testing there maximum pressure these cylinders can withstand. These two cylinders are selected by random sampling by the production in charge.

A. Current state map

After building the figure 3 current state map, it can be concluded that the particular industry is producing more than what is required, which is the first waste in lean waste category called overproduction.

Total of 1230 pipe was ordered from suppliers to make the demand complete.

From one pipe total of 8 * 30 liters water capacity cylinder pipes can be manufactured.

The Non-value added time was calculated as 160.26 hours (inventories in production line).

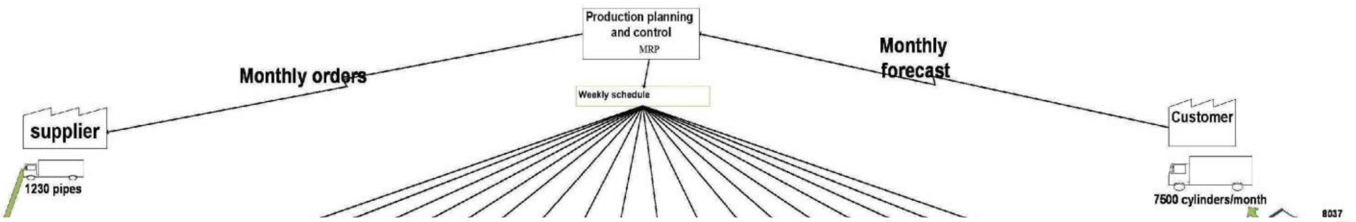
Table 1 contains alphabets A to R representing machining processes like pipe cutting, induction furnace(A), spinning machine (A),bottom milling, induction furnace(B), spinning machine(B), welding, heat treatment, hardness testing, neck cutting, neck drilling, neck threading, hydro-static test, air-leakage test, internal shot blasting, external shot blasting, data stamping and painting and packaging. Accordingly number of kanban cards required for each machining process is included in the table.

B. Ideal state map

After all these above Information, an ideal state map was implemented where a total of 7992 products were produced, which satisfied both the regular customer demand as well as 492 cylinders safety stock was also maintained. Figure 4 consists of ideal state map. Table 2 shows the data related for ideal state map

To complete this demand 1000 pipes where ordered from supplier.

Figure 3: current state map



Machine	a	b	c	d	e	f	g	h	i
Workforce	5	2	5	4	2	5	7	8	3
C/T(min)	4	3	5	3.30	3	5	6	166.8	0.25
C/O(min)	5	300	438	60	300	438	5	240	1
Uptime (%)	95	85	85	95	85	85	95	100	100
Batch size	1	1	1	1	1	1	2	36	1
Inventory (wip)	64	95	1	8	40	1	98	90	45
WIP Holding Time(min)	192	474.6	0.5	8	79.8	0.5	588	720	225

Machine	j	k	l	m	n	o	p	q	r
Workforce	2	2	2	9	4	10	5	4	8
C/T(min)	2.2	1.3	4	11	5	10	3.4	3	90
C/O(min)	15	15	60	5	2	78	60	10	10
Uptime (%)	95	90	95	85	100	85	95	95	100
Batch size	1	1	1	3	4	4	4	1	36
Inventory (wip)	7	3	13	185	21	254	130	60	50
WIP Holding Time(min)	1.16	1	6.5	739.8	63	2031.6	1039.8	180	50

Table 1: current state map

All the data related to create current state map is shown in table 1.

The industry was producing 9840 products at the end of the month, whereas only 7500 products was the customer demand The management policy is to keep 492 products as safety stock.

So the main waste highlighted from Current state map is of Overproduction which was the reason of higher level of work load and inventory which was needed to be balanced.

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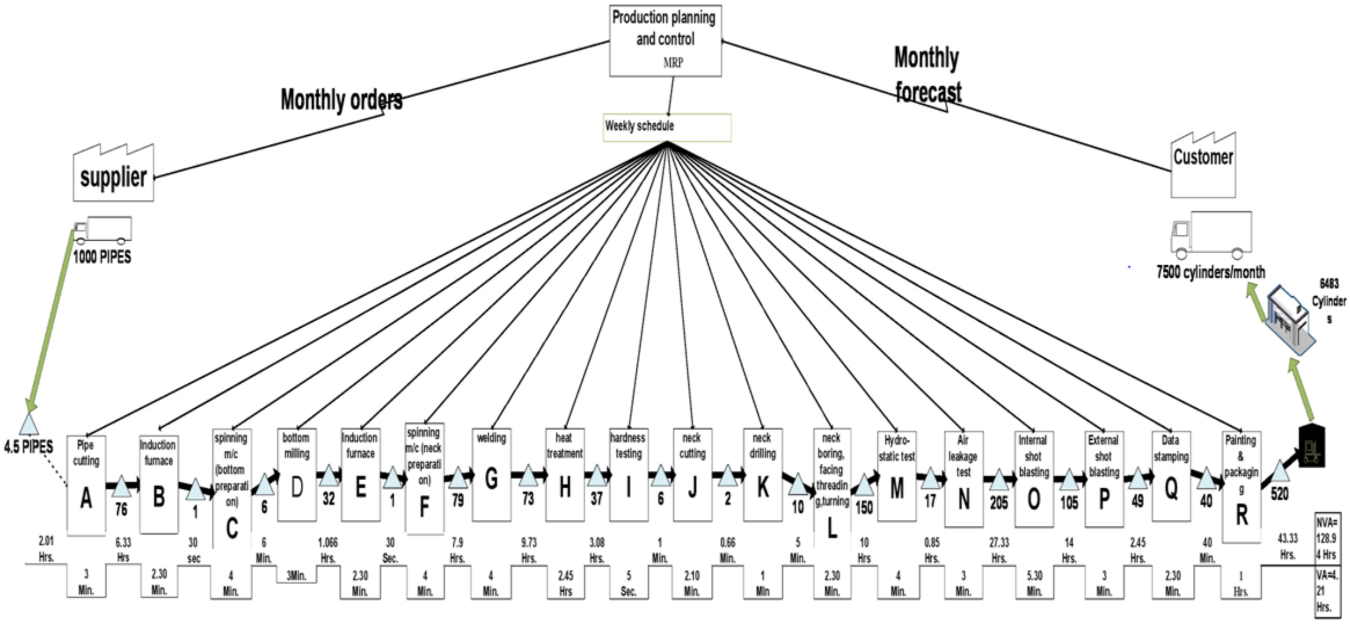
Figure 4: Ideal state map

Table 2: Ideal state table

The production of 7992 CNG cylinders was completed in 25 days. So a total 5 days of lead time was reduced.
One worker from pipe cutting machine (a) can be reduced.
The non-value added activities were calculated as 128.94 hours.

C. Future state map

After creating the ideal state map, a future state map was created which stated some changes in the work-in-process inventory time by implementing Automation between the stations.



Machine	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r
Workforce	4	2	5	4	2	5	7	8	3	2	2	2	9	4	10	5	4	8
C/T(min)	4	3	5	3.30	3	5	6	166.8	0.25	2.2	1.3	4	11	5	10	3.4	3	90
C/O(min)	5	300	438	60	300	438	5	240	1	15	15	60	5	2	78	60	10	10
Uptime (%)	95	85	85	95	85	85	95	100	100	95	90	95	85	100	85	95	95	100
Batch size	1	1	1	1	1	1	2	36	1	1	1	1	3	4	4	4	1	36
Inventory(wip)	36	76	1	6	32	1	79	73	37	6	2	10	150	17	205	105	49	40
WIP Holding Time(min)	120.6	379.8	0.5	6	63.96	0.5	474	583.8	184.8	1	0.66	5	600	51	1639.8	840	147	40

No. of inventories reduced= 9840-7992=1848.
After the reduction of overproduction, (160.26-128.94) 31.32 hours non-value added time was reduced.

Figure 5 shows the automation model. Automation model created is like of a plain inclined surface in which at one end pneumatic operated jaw was fixed. This Pneumatic operated jaw helped to carry the cylinder from one conveyor towards other without human interference.

Also the inclined plain surface provided good rolling action for the cylinder instead of using roller conveyors where the rolling action of cylinder was not much used.

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Figure 5: Automation model

Kanban card calculation:

Kanban card was calculated for every process. Container capacity was defined as 36 because the maximum batch size of heat treatment and painting is 36. Container capacity of spinning machine is considered to be 1 as the product from Induction furnace directly goes into spinning machine.
Average daily demand is 352 products and safety stock is 24 products.

Figure 6: Future state map

Daily working hours are 21 hours.
Number of kanban card (a) = (ADD* lead time + safety stock)/container capacity

= (352*7.35/1260 + 24)/36
= 0.72 =1

Production Instruction card =1
Production Withdrawal card =1
So, a total of 2 Kanban card is required at machine a.

Number of kanban card (c) = (ADD* lead time + safety stock)/container capacity

= (352*18.5/1260 + 24)/1
= 29.1 =29

Production Instruction card= 29
Production Withdrawal card= 29
So, a total of 58 Kanban card is required at machine c.

Table 3: No. of kanban cards

Machine	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
No. of kanban cards	2	2	58	2	2	66	2	2	2	4	4	4	4	4	4	4	4	4

A total of 174 Kanban cards is required in production line. From which, 124 kanban cards are for spinning machine only because of the less container capacity. Table 3 shows the number of kanban cards required for every machining process.
During the implementation of this automation model as well as kanban control system, non-value added activity was calculated as 15.15 hours. This was mainly because the cylinders were not directly handled by the operators.
Automation model and Kanban control system was applied to build the future state map. So a total of 113.79 hours (128.94-15.15) of non value added time was reduced with the help of this automation. Thus the production was completed in 21.3 days. I.e. a total of 3 more days of lead time was successfully reduced. Figure 6 shows the future state map and table 4 shows the data achieved n future state map.

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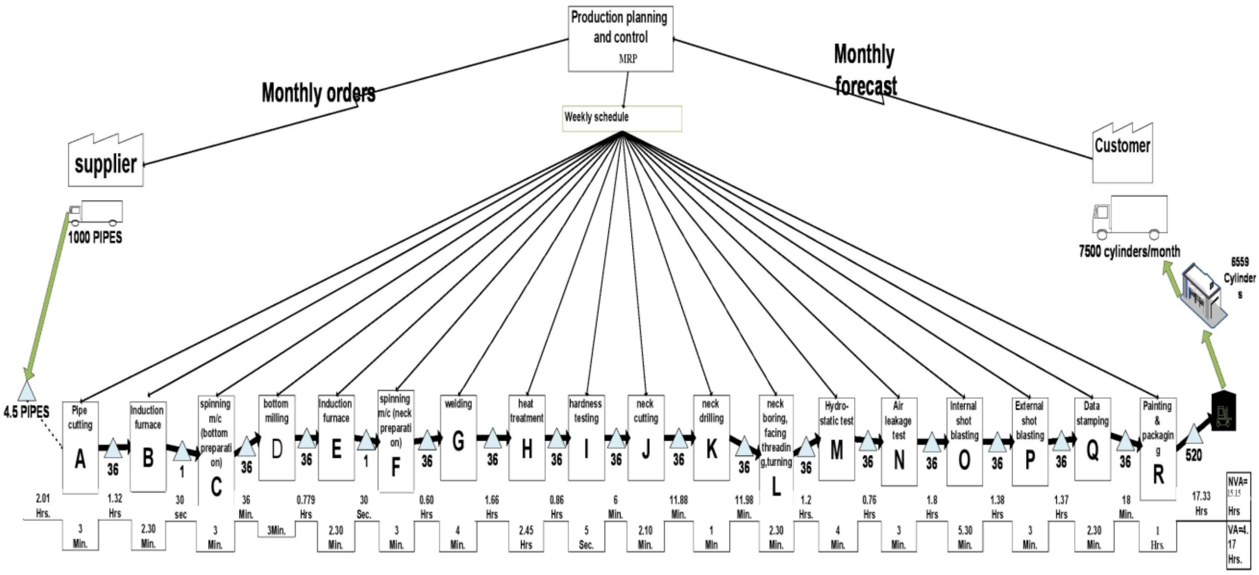
Table 4: Future state data

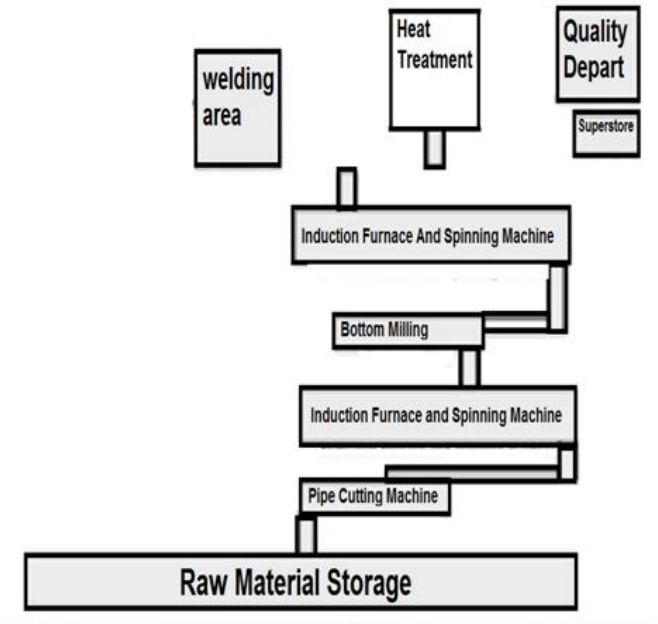


Due to automation between stations, total of six workers was reduced from pipe cutting, spinning, welding, heat treatment,

Machine	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r
Workforce	4	2	4	4	2	4	6	7	3	2	2	2	9	4	9	5	4	8
C/T(min)	4	3	5	3.30	3	5	6	166.8	0.25	2.2	1.3	4	11	5	10	3.4	3	90
C/O(min)	5	300	438	60	300	438	5	240	1	15	15	60	5	2	78	60	10	10
Uptime (%)	9	85	85	95	85	85	95	100	100	95	90	95	85	100	85	95	95	100
Batch size	1	1	1	1	1	1	2	36	1	1	1	1	3	4	4	4	1	36
Inventory(wip)	36	36	1	36	36	1	36	36	36	36	36	36	36	36	36	36	36	36
WIP Holding Time(min)	120.6	79.2	0.5	36	46.74	0.5	36	99.6	51.6	6	11.88	11.98	72	45.6	108	82.8	82.2	18

internal shot blasting stations in the future state map.

Figure 7: Superstore Implementation



A superstore was implemented in between the production line, so as to reduce the unnecessary movements of the workers. Figure 7 shows the implementation of superstore near quality department.

Workers unnecessary movements up and down till store and washroom:

Pipe cutting machine: (186meters*4)= 744 meters
Induction furnace: (184meters*2)= 368 meters
Spinning machine: (180meters*4)= 720 meters
Bottom milling: (170meters*4)= 680 meters
Induction furnace: (160meters*2)= 320 meters
Spinning machine: (140meters*4)= 560 meters
Welding: (120meters*6)= 720 meters

Heat treatment: (130meters*10)= 1300 meters

Total of 5412 meters was calculated as unnecessary movement of workers before the implementation of superstore.

Workers unnecessary movement up and down till superstore and washroom:

Pipe cutting machine: (60meters*4)= 240 meters
Induction furnace: (50meters*2)= 100 meters
Spinning machine: (54meters*4)= 216 meters
Bottom milling: (44meters*4)= 176 meters
Induction furnace: (30meters*2)= 60 meters
Spinning machine: (34meters*4)= 136 meters
Welding: (24meters*6)= 144 meters

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Heat treatment: (18meters*10)= 180 meters
Total of 1252 meters was calculated as unnecessary movement of workers after the implementation of super store. Therefore, 4160 meters of unnecessary movement of workers was reduced successfully by the implementation of superstore.

V. 6S IMPLEMENTATION

Finally, 6s was implemented in the store and production line, where different boxes sorted out and a specification tag was attached to them.
Boxes containing welding rods, gloves, Apron, first-aid kit, helmets, ear-protectors, paint and paint brushes, hydraulic hoses etc were sorted out with a tag mark and after that some boxes were delivered to the superstore so that downstream operators unnecessary movement is reduced.
Standardized work structure of daily clearing of machines was started which was held twice in one week. Workers were shown the importance and benefits of using safety instruments while working which created a safe environment in the industry. Downstream operators showed more interest in using the safety equipments as it was delivered to superstore rather than collecting it from store which operators considered as an hectic activity to walk far from their workstations towards store. Periodic maintenance schedule was started which changed from once in two month to twice in a month.

Before 6s implementation:
Figure 8 consist of image taken from store before 6s implementation. There was a huge mix up in the safety equipment's which was needed to be sorted out. Unless the safety equipment's in store was not sorted out and cleared, till then workers were working without using safety equipment, which caused high rework of materials, thus there was a need of implementing 6s system.

Before sorting and cleaning of boxes in store:

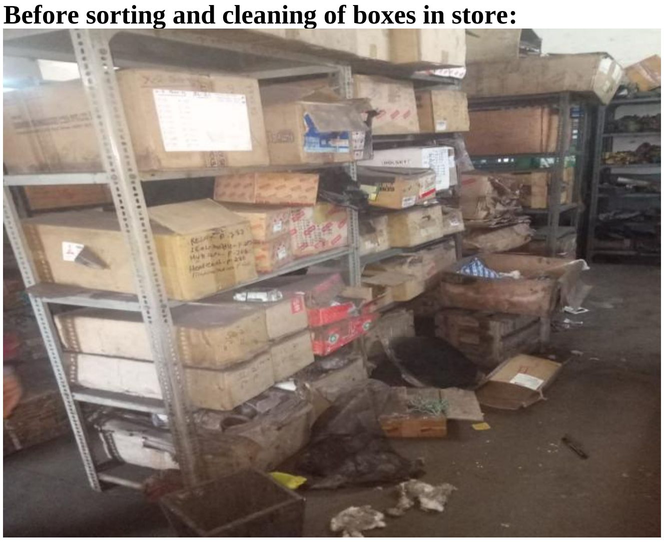

Figure 8: Before 6s implementation

After 6s Implementation
Figure 9 shows the images of store after the implementation of 6s.

After applying tag line for every specification and sorting the safety boxes, they were transferred to superstore so that workers can use these safety equipments frequently.
After sorting and cleaning of store boxes:

Figure 9: After 6s implementation

VI. CONCLUSION

Through the lean implementation, Successful Reduction of 1848 inventories was achieved due to removal of overproduction. A total of 113.79 hours of Non-value added time was eliminated by implementing automation and kanban control system between stations. 347 work-in-process inventories were reduced from production line due to kanban control system. Total of 6 workers were reduced due to automation model. While comparing current state and future state, total of 9 days lead time was reduced. A total of 4160 meters of unnecessary movement of workers was successfully reduced by the implementation of superstore. 6s was successfully implemented in store and production area. Standardized work structure of periodic maintenance was created which was once in two month to twice in once month, which helped reduction in breakdown/downtime of machines. Thus it can be stated that lean helps an industry towards enhancing its productivity without incurring more cost in the production of a particular product.

VII. FUTURE SCOPE

Kanban results can be compared via arena simulation for better optimization. Simulations can be used to highlight bottlenecks in production line. Plant utilization capacity can be much improved by developing a good layout i.e. setting up machines in U layout rather than line layout. Single minute exchange of dies can be implemented in hydro-static test stage when the grant crane drops down the cylinder so that productivity is increased. SMED can also be applied into processes which require high changeover time thus reduce the same.

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