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Process Improvement in Compressor Assembly Line Through Work Study

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Abstract*: In this paper, an attempt was made to improve the productivity of the line by reducing the cycle time of the stations. The assembly line under consideration is a mixed model assembly line producing three varieties of compressors products A, B and C majorly. Amongst them, Product C Compressors was critical, having a high Total Operating Cycle Time (TOCT), and was hence chosen for the study. Time study was done to identify the bottlenecks in the assembly line. Method study was then carried out to analyze the bottleneck stations to find the non-value added activities (3M–Muda, Muri and Mura). Various causes contributing to the high cycle time were brainstormed. Kaizens were identified to reduce the non-value added activities in the bottleneck stations. With the help of the Spaghetti diagrams, operator movements were analyzed and new layouts with much less operator movement were proposed. The Kaizens were successfully implemented and hence the lean wastages at the bottleneck stations were reduced. Thus, the cycle time of the bottleneck stations was eliminated and the Total Operating Cycle Time was decreased by 13% from 225 minutes to 195 minutes.

***Keywords*: Total Operating Cycle Time, Bottleneck analysis, Non-Value Added activities, Spaghetti Diagram.**

1. Introduction

In this paper, the progress was conducted in an industry that manufactures air-compressors. The industry manufactures many varieties of compressors. Hence there are high varieties of variations in a similar product. The facility has 5 main assembly stations and 5 subassembly stations. The product variety chosen for study is having high Total Operating Cycle Time. As the assembly line is a mixed model assembly line, the workstations will handle different varieties of products. The stations 1,3,4,5, cooler and tank subassembly stations were identified as a problem area. The stations 1, 3, 4, 5, cooler and tank subassembly stations were identified because these stations having the bottlenecks, as the processing time in these stations exceeded the processing time at the other stations. Hence the scope of our study was limited to the bottleneck stations.

2. Literature review

The focus of the literature survey was to gather information about the assembly line, the ways in which bottlenecks are reduced and to understand the techniques to improve productivity [1]. studied that it can be concluded that, Critical lean tools when effectively combined with Work Study Methods, a unique leaner system can be formed which will be the universal solution for any type of industry having any sort of problem regarding the productivity.[2] has suggested a work-study technique to analyse the current situation of the industry and also helps to identify non-productive time which can be reduced to increase productivity.[3] studied that the issues related to the product design and geometry (Method), the workstation layout and ergonomics (Machine), the workers (Man), and the tools and equipment (Material). The 4M approach is based on five steps that allow analyzing and improving both the product design and the assembly line: (i) video recording, to capture the assembly tasks, (ii) assembly task analysis, to investigate in detail each operation, (iii) identification of criticalities, to derive the most critical tasks, (iv) 4M method application, to group the assembly issues according to the four different classes, and (v) re-design and re-layout, and implement.[4] stated that the successful Lean Manufacturing System implementation needs integration and simultaneous implementation of Lean elements along with the proper sequence.[5] studied that the time study can be done in many ways, and the results are compared and measured many times. As a result of the study, the production capacity is increased.

3. Methodology

As mentioned earlier, the objective of the study was to reduce the high cycle time of the bottleneck stations. The methodology adopted in this regard is shown in figure 1. The current state of activities was mapped, following which the time and process studies were undertaken. The takt time was calculated. The consolidation of the time and process study was to identify the reasons for cycle time exceeding the takt time. The action was implemented. Operator trained and standardized.

A. Data collection

Time study was done for the assembly of air-compressors in bottleneck stations. Firstly, micro and macro processes were identified and each process was timed separately. This study

Table 1
Time study for all stations

Station	Time in Minutes			
	Machine 1	Machine 2	Machine 3	Average Time
Motor wiring subassembly	10.68	12.36	10.68	11.24
Motor Airend subassembly Operator A	12.60	10.20	14.88	12.56
Motor Airend subassembly Operator B	14.28	13.20	14.30	13.93
Cooler subassembly	20.76	18.36	19.56	19.56
Moisture separator subassembly	6.00	6.00	6.34	6.11
Tank subassembly	13.68	15.48	17.74	15.63
Station1 Operator A	15.36	14.40	14.09	14.62
Station1 Operator B	11.04	10.20	9.31	10.18
Station2 Operator A	12.60	13.20	13.80	13.20
Station2 Operator B	13.92	13.56	14.22	13.90
Station3 Operator A	15.96	14.64	15.43	15.34
Station3 Operator B	8.76	8.52	8.34	8.54
Station3 Operator C	7.56	7.32	7.50	7.46
Station4 Operator A	16.44	18.36	15.78	16.86
Station4 Operator B	15.60	16.98	18.00	16.86
Station5 Operator A	12.72	9.84	15.35	12.64
Station5 Operator B	17.88	18.00	13.37	16.42
Assembly TOCT	225.84	220.62	228.68	225.05

helps us to analyze various works with respect to time. Table 1 shows the various time studies for the workstations.

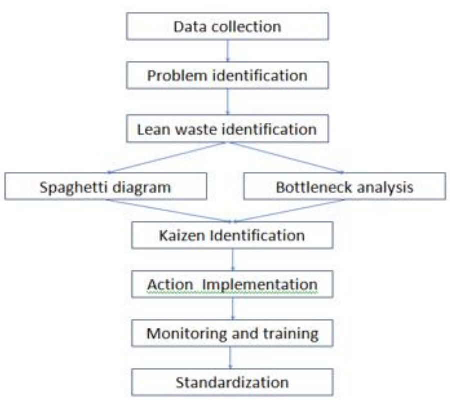

Fig. 1. Methodology to reduce cycle time

B. *Problem identification*

Available time in minutes per day =510 minutes
Current demand for units per day =28 units
Current takt time =510/28
Current takt time =18 minutes
Targeted demand for units per day =36 units
Expected takt time =510/36
Expected takt time =14 minutes

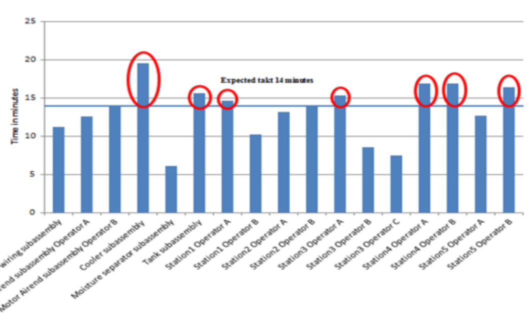

Fig. 2. Bottleneck identification

C. *Spaghetti diagram*

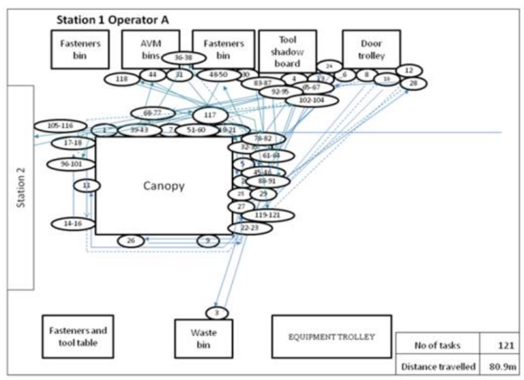

Fig. 3. Station – 1 Operator A

The above figure represents the distance moved by the operator. This spaghetti diagram was used to plot the distance moved by the operator in all stations. In the above spaghetti diagram, the distance moved by the operator is 80.9m. Likewise, for all Bottleneck stations are analysed and a new layout is proposed with much less operator movement.

4. Results and discussion

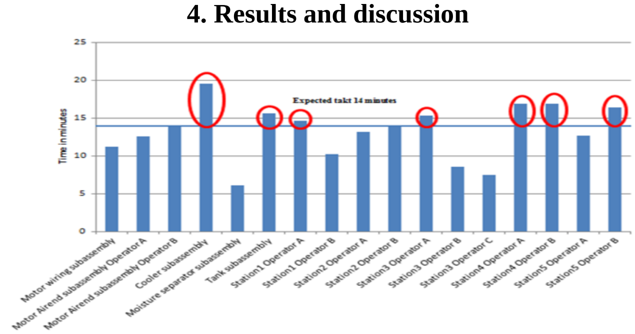

Fig. 3. Before KAIZEN implementation

Table 2
Kaizen identification

MODEL	STATION	PROBLEMS	KAIZENS	BENEFITS
Product C	1	The High time required to orient the emergency stop button	Emergency stop button sticker can be pasted initially.	Time reduced = 0.39 min
Product C	1	High time and fatigue in removing the top roof	Instead of 10 bolts, only 2 bolts should be fixed at the supplier end	Time reduced = 1.5 min
Product C	Tank Subassembly	Improper fitting of Allen box bit with extension rod	Weld the Allen box bit with an extension rod in tank SA	No loosening of Allen box bit from the rod
Product C	1	Canopy cover removal is a non-value added activity and increases cycle time	Removal of covers of the canopy before assembly stations.	Time Reduced = 0.48 min
Product C	5	Unwrapping boxes is a non-value added activity and increase cycle time	Unwrap boxes in stores itself	Time Reduced= 0.13 min
Product C	3	Cycle time increases in strainer valve components assembly	Strainer valve components can be an assembly as a single component	Time saved=2.18 min
Product C	1	Operator fatigue in fitting control panel	Control panel fixture should be used	Time-saving
Product C	1	High time and confusion in fitting AVMs	2 AVMs for Air end can be fixed at supplier end	Time Reduced=0.75 min
Product C	5	Wingnut which is fixed at the supplier end is being removed again to fit air filter	Wingnut and washer in the air filter can be placed in a bin separately	Time reduced=0.28 min
Product C	Cooler Subassembly	High time in fan wiring assembly	Fan wiring should be done at supplier end	Time reduced= 3.5 min
Product B	5	The top roof cover is fitted separately. Its time-consuming process	Top roof cover can be fitted before conducting a leak test	Time reduced = 0.84 min
Product B	5	The air filter has to be reassembled again	The Air filter can be assembled in the required position from the supplier end	To reduce the Re-assemble time
Product A	4	Operator confuses to identify cooler inlet and outlet hoses since its very similar	Change colour for cooler inlet and outlet hose	To avoid confusions
All model	All stations	Operator movement for picking and placing tools is high	The operator can wear a belt which consists of major tools(spanner, screwdriver, cutter, marker, box bit)	To avoid confusions and time saved= 2.55 min
All model	All stations	Grease gets to stick to the operator's hand and sometimes excess grease is applied	Use grease tube or grease gun to apply grease during a process	To avoid excess application of grease
All model	Cooler Subassembly	High time to remove the screws in the fan	Use battery gun instead of screwdriver for removing the screws	Time reduced = 1.2 min
All model	Cooler Subassembly	Hooke used in lifting scratches the cooler body	Use a rubber brush to cover the sharp edge of the hook	To avoid scratches in the products
All model	4	High time for a pressure sensor assembly	Pressure sensor assembly wiring should be done at the supplier end	Time Reduced = 2.6 mins

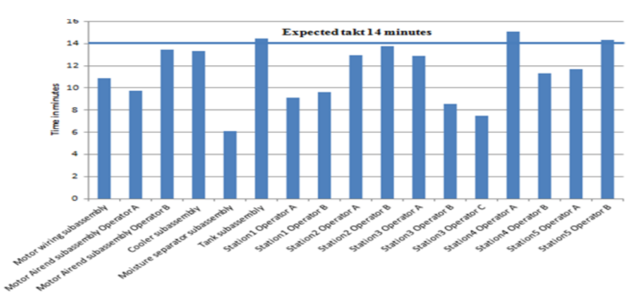

Fig. 4. After KAIZEN implementation

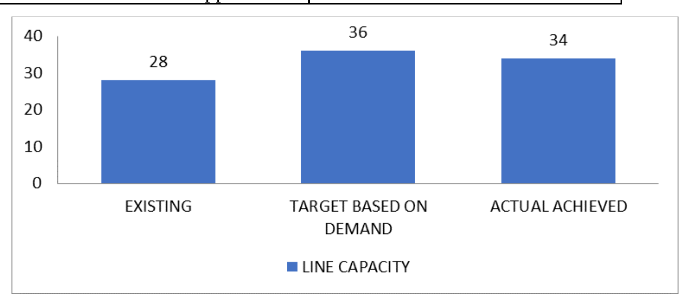

Fig. 5. Results summary

The table is a representation of Total Operating Cycle Time before the implementation of kaizens and after implementations. The bottleneck stations which was having high cycle time is reduced by implementing the identified kaizens.

Table 3
Comparison Summary

Stations	Average Time	
	Before implementations	After implementations
Motor wiring Subassembly	11.24	10.86
Motor Airend Subassembly Operator A	12.56	9.75
Motor Airend Subassembly Operator B	13.93	13.44
Cooler Subassembly	19.56	13.3
Moisture Separator Subassembly	6.11	6.11
Tank Subassembly	15.63	14.42
Station1 Operator A	14.62	9.12
Station1 Operator B	10.18	9.62
Station2 Operator A	13.2	12.94
Station2 Operator B	13.9	13.73
Station3 Operator A	15.34	12.86
Station3 Operator B	8.54	8.54
Station3 Operator C	7.46	7.46
Station4 Operator A	16.86	15.05
Station4 Operator B	16.86	11.3
Station5 Operator A	12.64	11.66
Station5 Operator B	16.42	14.35
Assembly TOCT	225.05	195.91

Table 4
Results Summary

Line A	Existing	Target Based on Demand	Actual Achieved
Line Capacity	28	36	34
Assembly Time	225 Minutes	-	195 minutes

Thus the expected line capacity was achieved by process improvement. Thus the process improvements were carried out successfully. The Total Operating cycle time was reduced from 225.5 minutes to 195 minutes.

5. Cost analysis

Table 5
Cost analysis-1

Line A	Existing	Actual achieved
Labour cost per hour	Rs. 100	Rs. 100
Labour cost per minute	Rs. 1.67	Rs. 1.67
Toct	225.5 min	195 min
Labour cost per machine	Rs. 426.68	Rs. 325.65
Line capacity	28 units	34 units
Labour cost per day	Rs. 11947	Rs.11072

A. Inference

The labour cost per day is reduced from Rs.11947 to Rs.11072.

Reduction in labour cost per day =Rs.875
Reduction in labour cost per month =Rs.17500
Reduction in labour cost per annum =Rs.210000

Table 6
Cost analysis-2

Line A	Existing	Actual Achieved
Price Per Unit	Rs. 400000	Rs. 400000
Line Capacity	28 Units	34 Units
Cost of Goods Sold Per Day	Rs. 11200000	Rs. 13600000

B. Inference

The cost of goods sold per day is increased from Rs.11200000 to Rs.13600000.

Increase in cost of goods sold per day = Rs. 2400000
Increase in cost of goods sold per month = Rs. 48000000
Increase in cost of goods sold per annum = Rs. 576000000

6. Conclusion

Thus the expected line capacity was achieved by process improvement. Thus the process improvements were carried out successfully. The Total Operating cycle time was decreased from 225.5 minutes to 195 minutes. By conducting work study and implementing kaizens the productivity was increased by reducing TOCT. The Labour cost is decreased by 7.3% and the cost of goods sold per day is increased by 21.4%. The most important result of lean manufacturing is that they do not require high-cost technology and investment. Lean manufacturing has gained popularity over many years. In fact, lean manufacturing methodology requires all the employees in an organization to work together and create a never-ending effort to continuous improvement.

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