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Production Line Optimization using Lean Tools: A case study of Automotive Part Manufacturing Company

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Abstract - *Lean Manufacturing is the management philosophy which is derived from the Toyota Production System (TPS). The main aim of lean manufacturing is to eliminate the waste and increase the productivity of any organization. In any organization improving the productivity is important. The study was conducted in an automobile part manufacturing company situated in Pune, India. The objective of the paper is to help the organization improve the output productivity so as to meet the customer demand. This research paper includes the production line optimization by making use of various Lean Tools like Spaghetti diagram, Single Minute Exchange of Die (SMED), Production Planning, Manpower optimization by Toyota Production Way (TPS), Standard Work Combination Table (SWCT). By using this tools, the output productivity of the production line was increased by 32%, Back tracking of the material is eliminated, Manpower is reduced by 22% and the Setup time is reduced by 41-60%.*

Key Words: Productivity Improvement, Production planning, Spaghetti Diagram, SWCT, TPS way, Manpower optimization, SMED.

1. INTRODUCTION

This research paper includes the study conducted in an automobile part manufacturing company, at a production line having two cells soft cell and hard cell. Soft cell is machining of parts before heat treatment and Hard cell is machining of parts after heat treatment. Meeting with the customer demand is one of the prime objective of any organization to grow and strive in a competitive market. The problem faced in the production was lack of planning so that the quantity of 1600 Nos. for 17- part variety was not able to meet. In order to meet customer demand improving the productivity was necessary. Productivity was improved by using lean tools like method and time study, production planning, spaghetti diagram, manpower optimization by TPS way, Standard Work Combination Table (SWCT), Single Minute Exchange of Die (SMED).

Time study is conducted for both planning and control of operations. It's essential to find out the time required for doing a particular work which includes repetitive and non-repetitive activities [1]. It provides the standard time to complete any task for either a worker or for the machine. Standard time is required for estimating the time required to meet the demand [2]. It also helps us to calculate the capacity, hourly output and helps in production planning. Use of Gantt charts helps to plan the schedule ahead. Spaghetti diagram is visual representation of the flow of either material or work flow. It helps us track the movement and eliminate excess movement or back tracking of the material [7]. Unnecessary movement leads to loss in production time leading to waste [8]. Toyota production system helps an organization to optimize as per the requirement of the customer [6]. Takt time is amount of time required to produce the product to meet customer demand. Toyota production system helps to optimize manpower keeping the work content and that Takt time in consideration. To optimize manpower one man multi machine can be implemented. Standard Work Combination Table (SWCT) helps to identify the idleness of the operator or the machine and help to find out if 1 man multi machine is possible or not. Whenever there is pattern production frequent setup changes are required. Setups are done so as to prepare the machine for production of other part [12]. Setup time or change over time is the time period from last good piece of last batch to first good piece of new batch [10]. Setup time need to be less so the down time is less and lowers the manufacturing cost. It improves machine utilizations. Thus helping in increasing the productivity.

2. LITERATURE REVIEW

A Case Study of Productivity Improvement by using IE Tools. Authors - Satish Keru Raut, Kedar M. Relekar. This research paper includes the application of time study in an engine block manufacturing company. Productivity problem between the shift and the management lead to need of time study. It helped them set standard for a production line.

Increasing in Productivity by Using Work Study in a Manufacturing Industry. Authors - Shantideo Gujar, Dr. Achal S. Shahare. In this research paper work study tools were used to increase the efficiency and productivity of the plant. It helped to improve the practices and increase in the production rate by 11%.

Productivity Improvement by Work Study Technique: A Case on Leather Products Industry of Bangladesh. Authors - Md. Abdul Moktadir, Sobur Ahmed, Fatema-Tuj-Zohra and Razia Sultana. In this research paper using work study as a tool to identify the bottleneck, then taking time study to find out standard time productivity increased by 12.71%.

Gantt charts: A centenary appreciation. Author - James M. Wilson. In this research paper its shown how man and machine planning is done by using gantt chart.

Use of Spaghetti Diagram for Identification and Elimination of Waste Movements in Shop Floor for OEE Improvement: A Case Study. Authors - Nagaraj A Raikar, Prasanna Kattimani, Gaurish Walke. In this research paper how to increase in the productivity of a line so as to meet customer demand is given by reducing frequent breakdown and long change over time. Unnecessary movement was reduced by 70%.

Spaghetti diagram application for workers' movement analysis. Authors - Katarína Senderská, Albert Mareš, Štefan Václav. In this research paper with the help of spaghetti diagram time, distance travelled is identified, evaluated and focus on reducing it.

Application of spaghetti chart for production process streamlining. Case study. Author - K. Hys, A. Domagała. In this research paper how to improve the process conducted for an operation is given with the help of spaghetti diagram. Eliminating the unnecessary process with the help of spaghetti diagram 26.6% of movement in steps have been eliminated.

Standardized work in TPS production line. Author - Nurul Hayati Abdul Halim, Ahmed Jaffar, Noriah Yusoff, Ahmad Adnan Naufal. In this research paper how to use SWCT chart in Toyota production system is shown, with the use of data like manual time, walking time, auto cycle time of a machine so as to see if 1 man multi machine is possible or not. Showing the idleness of either the operator or the machine.

Literature Review and Implications of Standard Work Implementation in Indian Industry- A Case Study. Authors - Rakesh Kumar, Dr. Vikas Kumar. This paper presents

implementation of Standard work enabler of Lean Manufacturing in a manufacturing system. Standard work combination tables specify exactly how all work is performed. Thus finding the idle time of the operator and improvement of the labor efficiency by providing work to eliminate idleness.

Improving SMED in the Automotive Industry: A case study. Authors - Ana Sofia Alves, Alexandra Tenera. In this research paper various steps of SMED is given so as to reduce the change over time of the machine. By following the steps of identifying the internal and external activity, then converting internal to external, then streamlining all aspects the setup time was reduced by 45%.

Changeover time reduction using SMED technique of lean manufacturing. Authors -Yashwant R. Mali, Dr. K.H. Inamdar. In this research paper we come to know how low setup time is required where there is low volume and high variety of products. Here by identifying the internal and external activity, separating them, the converting internal activity to external activity. Making use of SMED trolley, setup time is reduced by 50%.

Application of SMED Programme of Lean Manufacturing for Improving Overall Equipment Efficiency -A Case Study. Authors - Gaurav Saini and Er. Harvinder Lal. In this research paper in forging shop and forging press was selected for reduction in setup time by using of single minute exchange to die tool. By converting internal to external activity, making use of pneumatic spanner, making use of SMED trolley maintaining 5S, setup time was reduced from 209.36 min to 167.09 min.

Implementation of SMED Technique to Reduce Setup Time of Band saw Cutting Machine. Authors - Shashikant Mendhe, Prof. M.G. Rathi. In this research paper a band saw machine has been selected for reducing the setup time. Analyzing the setup procedure by taking video. Then identifying internal and external activity, converting internal to external, validation of the improvement such as 5S, parallel activity was implemented. The setup time was reduced by 75%.

Improving Line Efficiency & SMED Study. Author - Ashish Dhankhar, Sanjeev Kumar. In this research paper the case study is conducted in an assembly plant, where factors affecting line efficiency and SMED are identified and dealt with. Factors like non-availability of material, non-availability of operator, machine break down etc. were identified. Video of Setup was taken then by separating internal and external activity and converting internal to external activity there by reducing the setup time. The line efficiency was increased from 69.63% to 71.27%.

Reduction in Setup time on Rubber Moulding Machine using SMED Technique. Authors - Mr. Sanket P. Gaikwad, Mr. Shivprasad S. Avhad, Mr. Swapnil S. Pawar, Prof. Pradnya R. Thorat. This paper includes the implementation of SMED technique for moulding of rubber to metal phosphate components for production of anti-vibratory mountings which requires frequent changeover. Implementation of new scissor type stackers (two numbers), New standardized T-bolts, heat resistant roller bearing with spring cushioning, mould heating platen, shadow board, mould storage rack with rollers helped reduce the setup time from 2 hours to 8 minutes.

3. PROBLEM STATEMENT

Meeting customer demand is one of the major factor which any organization has to fulfill. The production line where the study is done contains 17-part variety. As the customer demand increased from 1100 to 1600 for 1st month plant was not able to meet customer demand. Further there was back tracking of material and material flow was not properly streamlined (flow was crisscross), Excess manpower and more change over time. Further in steps followed to solve the problem are mentioned in methodology.

4. METHODOLOGY

4.1 Data collection

For optimization of the production line the following date is to be collected -

Identify the part family produced on the production line. There are 3 main Types of parts namely Shafts, Gears & Clutch body they are further divided in to various parts, the classification of these parts are shown in the below Fig. 1.

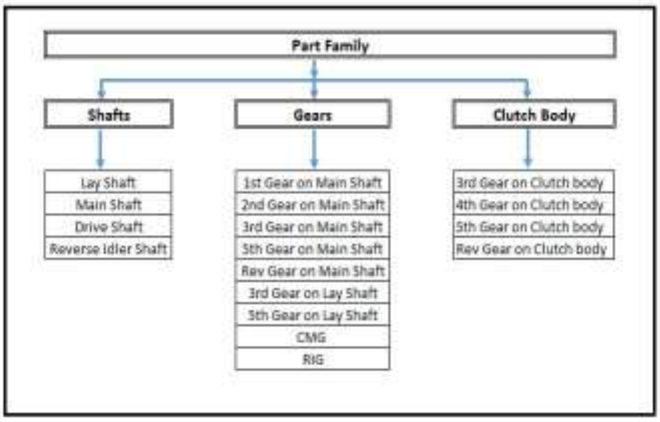

Fig- 1: Part Family

After Identifying the parts collect the data of the Processes through which they pass with the help of the Process flow diagram and for better understanding making Product-Process matrix for soft cell as well as Hard cell. The Product-Process matrix is shown in the below Fig. 2. & Fig. 3

Fig- 2: Soft Cell Product Process Matrix

Fig- 3: Hard Cell Product Process Matrix

Now getting the information and Listing down the types of machines are there in the production line. Discussing with the line supervisor constrains of machine is duly noted, as to which part has specific machine for the operation and which parts can be machined on any machine.

Conduction Time & Motion Study in order to determine the time required for the part to be machined. The data collected with the help of Time Study includes the Cycle time, Loading-Unloading Time, In-process Inspection Time.

In time study the following allowances were given as shown in the Fig. 4.

Sr.No.	Allowance Description	Allow. (%)
1	Personal Need	5.0%
2	Basic Fatigue	4.0%
3	Posture (Standing,Bending, so wherever Applicable)	2.0%
4	Noise (wherever Applicable)	
5	Fumes (wherever Applicable)	
	Summation	11%

Fig- 4: Allowance Table

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Stop watch time study was taken and standard time for each and every part was found out.

In the below Table 1. find the Time Study Sheet of a machine in which standard time is calculated for a part to be machined.

Table- 1: Standard Time calculation sheet

Time Study Sheet			
Machine	Shaping SN4		
Part :	1st Gear on Main Shaft	1st Shift	
Sr.No.	Element Desc.		
A	Recurring element :		
1	Pick up the part	2	
2	Load the Part to the machine	8	
3	Start Auto Cycle	240	
4	Clean using Pnuematic air gun	2	
5	Unload the job	9	
	Sub total	261.00	
B	Non recurring element :		
1	Setup Time (Batch Size 400)	9.0	
	Normal Time	270.0	
	Manual time	21.0	
	Machine time	240	
	Relaxation Allownace (11 %)	4.0	
	Standard Time in sec	274.0	
C	Autocyle elements (parallel to element 3)		
1	Inspect the Job	15	
2	Keep Bins from Input to Output Sliders	10	
	Sub total	25.0	
			Quantity/Hour
	1st shift Output	83	11.4
	2nd shift Output	83	11.0
	3rd shift Output	83	11.0
	Per Day output	249	

As there are various parts and they share common machine which is pattern production there are setups so initially collecting the data of current setup times.

4.2 Production Planning for1600 quantities

As we knew the cycle time and time required for each parts number of days required for 1600 quantity was calculated. Planning was done with the help of gantt chart so as to achieve a quantity of 400 per week to get 1600 at the end of the month. A week planning was made and given to the production and the same planning was to be followed for the next 3 weeks. The gantt chart of the planning is given is the Fig. 5. Below

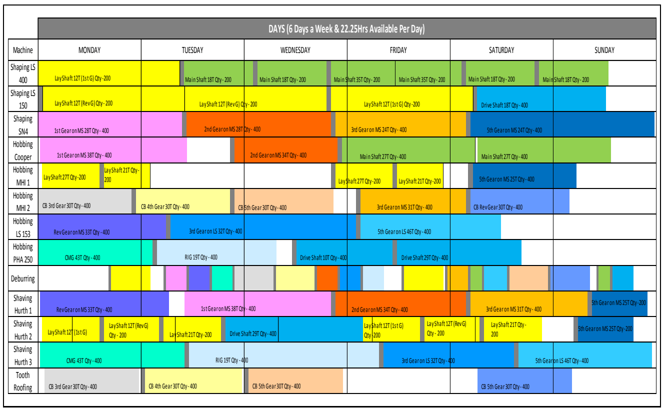

Fig- 5: Gantt Chart of production Planning for 1 Week

4.3 Material Movement Tracking

While conducting the study it was observed that there are mix up of the part parts and back tracking of the material. In order to prevent the mixing of the material and the back tracking spaghetti diagram was drawn. In the Fig.6. Material movement of all the parts in soft cell is plotted.

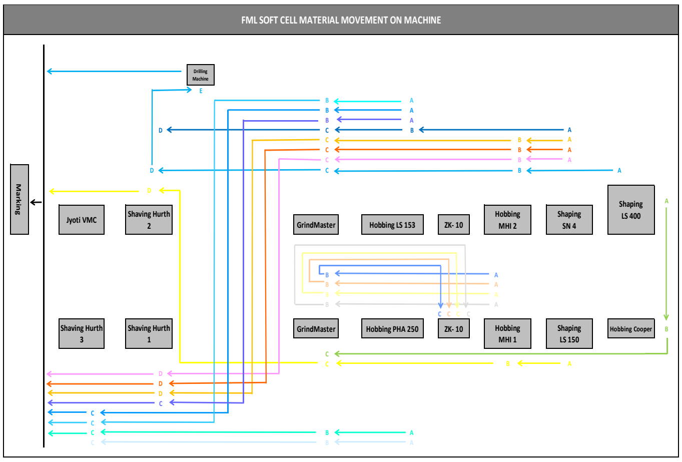

Fig- 6: Material movement before Layout change

After plotting the material movement diagram it was observed that there is back tracking of the material and crisscross flow. So layout changes were made accordingly and as per the layout changes the material flow is given in the Fig. 7. Below.

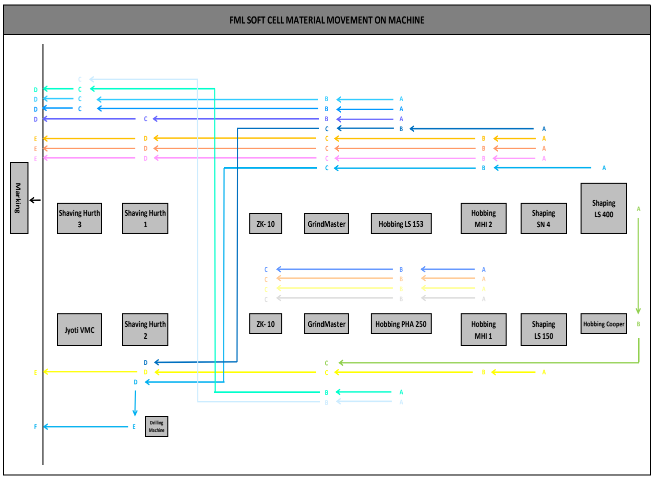

Fig- 7: Material movement after Layout change

After layout changes were made there is a stream line flow and the back tracking of material is eliminated.

4.4 Manpower optimization by Toyota Production (TPS) Way

The following steps are used to calculate the optimized manpower.

Soft Cell →

Step 1 - Takt Time (TT) Calculation

Takt time is the rate at which the part is to manufacture in order to meet the customer demand. It is calculated by

Takt Time = Available Time/Demand

Now the Total Time Available in a month is 25 days & Demand is 25600 Quantity (1600 parts each)

Takt Time = 79 Sec

Step 2 - Actual Takt Time (ATT) Calculation

Actual Takt Time (ATT) = TT X 0.85

Actual Takt Time = 67.15 Sec

Step 3 - Manpower Calculation & Allocation

Manpower = ΣCT/ATT

ΣCT is the Manual work content, Calculating the Manual work content for Soft Cell.

Soft Cell ΣCT = 513 Sec

Manpower (Soft Cell) = 8 Manpower

Hard Cell →

Step 1 - Takt Time (TT) Calculation

Takt time is the rate at which the part is to manufacture in order to meet the customer demand. It is calculated by Takt Time = Available Time/Demand

Now the Total Time Available in a month is 25 days & Demand is 20800 Quantity (1600 parts each)

Takt Time = 96.27 Sec

Step 2 - Actual Takt Time (ATT) Calculation

Actual Takt Time (ATT) = TT X 0.85

Actual Takt Time = 81.82 Sec

Step 3 - Manpower Calculation & Allocation

Manpower = ΣCT/ATT

ΣCT is the Manual work content, Calculating the Manual work content for Hard Cell.

Hard Cell ΣCT = 289 Sec

Manpower (Hard Cell) = 6 Manpower

After calculation of the manpower, allocation manpower was done Fig. 8. and Fig. 9 will show the manpower allocation below

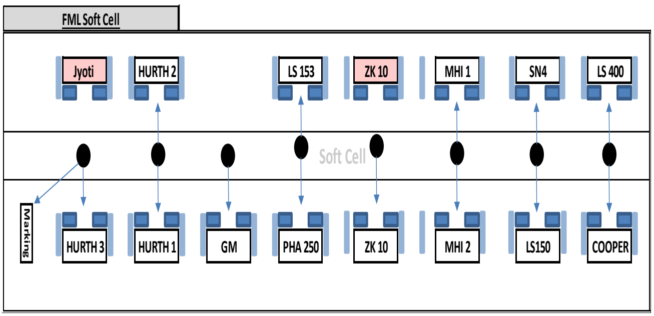

Fig- 8: Manpower allocation in Soft Cell

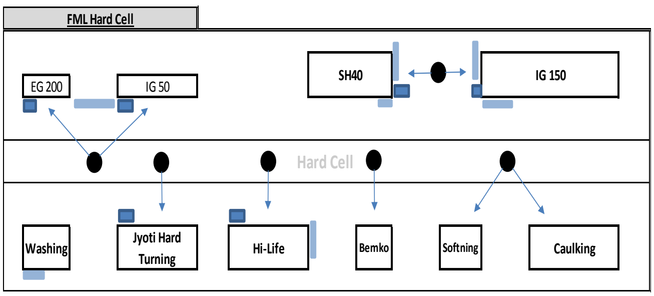

Fig- 9: Manpower allocation in Hard Cell

Step 4 - Preparing Standard Work Content Table (SWCT) where 1 man 2 machine is implemented for both Soft & Hard cell.

The Standard Work Combination Table is shown in the Fig.10. below. After drawing the SWCT chart wherever there was possibility of 1 man 2 machine it was implemented.

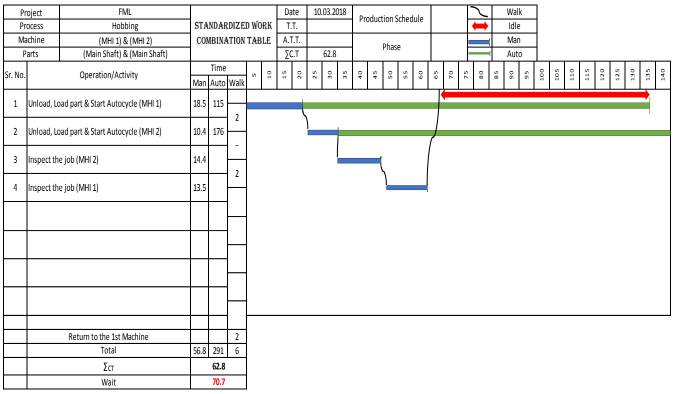

Fig- 10: SWCT Chart for 1 Man 2 Machine

With the help of this the manpower was optimized (reduced).

4.5 Setup time reduction with SMED Technique

The following steps were used in the SMED technique.

Step 1. Do the video recording of the whole setup process from last good piece of the last batch to the first good piece of the next batch.

Step 2. Do video analysis and list down all the activities

Step 3. Identify the Internal and External Activities

Step 4. Convert Internal activity to external activity where ever possible. If parallel activity can be done implement it.

Step 5. Design the proposal including the improvements, which activity to be performed by whom

Step 6. Implement the improvements suggested and release a standard procedure to perform the setup.

Step 7. After the suggestions have been implemented validate the whole process.

Table- 2: Activity Recorded & Identified as Int. or Ext.

Step No.	Process (Operation)	Time (sec)	Activity Type
1	Bring Hob for the next setup (5th Gear on Lay Shaft)	110	I
2	Bring Spanner, Hammer, Allen Key, Pipe	681	I
3	Clean the fixture and the hob used for 2nd gear MS	10	I
4	Rotate the fixture by pressing the button on the control pannel and clean the fixture	20	I
5	Shift the location of hob away from the fixture	30	I
6	By Using the Allen Key to remove the screw to remove the fixture (2 screws)	65	I
7	Rotate the fixture by pressing the button on the control panel and remove the rest of the 2 screws	35	I
8	Hold the top of the fixture by left hand & Rotate the fixture to loosen it and then remove it	25	I
9	Keep the Fixture on the table and clean it with the cloth	5	I
10	Remove the base of the fixture by holding it and rotating the fixture holder and keep it on the table	92	I
11	Take the base of the fixture for 5th Gear LS and clean it	12	I
12	Fix the base of the fixturefor 5th Gear LS	109	I
13	Clean the fixture & fix it by tightning it	44	I
14	Put Screws on the fixture and tighten it with the help of Allen key	155	I
15	Go and Bring Dial Guage	10	I
16	Attach the dial guage to the Hob side to set the rotation of the fixture	5	I
17	Rotate the fixture to check the deviation and adjust it by hammering it with the hammer	216	I
18	Remove the Dial guage and keep it on the table	5	I
19	Rotate the Hob holder and bring it in the position to remove it	36	I
20	Use Spanner & Hammer to loose it on both the ends and remove the hob	104	I
21	Take the hob Holder to the hob clamp to remove the hob	8	I
22	Clamp the Holder and loose the hob for 2nd Gear MS	55	I
23	Clean the hob holder	30	I
24	Clamp the Holder for putting the hob for 5th gear LS	5	I
25	Bring the 5th gear ls Hob to the clamp	10	I
26	Put the Hob for 5th gear LS in the holder and tighten it	70	I
27	Take the hob back to the machine	10	I
28	Clean the inside of the machine where hob is to be clamped	10	I
29	Fix the Hob in the machine by clamping it and tightning it with the help of the spanner	110	I
30	Take the dial guage to set negligible deviation while rotation of the hob, attach the dial guage to the opposite side of the Hob holder and rotate the Hob to check the deviation	251	I
31	Take the 5th Gear LS job and clean it	15	I
32	Load the Job	25	I
33	Adjust the Parameters on the machine	337	I
34	Close the Door & Start the machine	5	I
35	Adjust the Hob and the job distance by size adjustment	1203	I
36	Fill the setup control sheet	216	I
37	Take the job to CMM for inspection	1500	I
38	Bring the Bin which contain the input for the machine	300	I
39	Load and start the machine	12	I

Table- 3: Internal Converted to External Activities

Step No.	ECRS E	C	R	S	Internal to External	Improvements	Time after Improvement	Time Saved (Sec)
1			✓		External	Can be brought while the machine is running	110	0
2				✓	External	Maintain 5s and make separate trolly for only keeping tools which can be bought while machine is running	60	621
3			✓			Cleaning can be done afterwards	0	10
4							20	0
5							30	0
6							65	0
7							35	0
8							0	25
9							5	0
10							92	0
11							12	0
12							109	0
13			✓		External	Cleaning can be done before, while machine is working	0	44
14							155	0
15			✓		External	Can be brought along with other tools	0	10
16							5	0
17							216	0
18							5	0
19							36	0
20							104	0
21			✓		External	Can be done by other operator ie deploying 1 helper (Operator Operating that Machine)	0	8
22			✓		External		0	55
23			✓		External		0	30
24			✓		External		0	5
25			✓		External		0	10
26			✓		External		0	70
27			✓		External		0	10
28							10	0
29							110	0
30							251	0
31				✓	External	Write down the parameters which are needed to be fed in the m/c saving time to search it on control plans	0	15
32							25	0
33							337	0
34							5	0
35							0	1203
36			✓		External	Can be filled after setup is done and machine is running	0	216
37			✓		External	No need to wait for the report, supervisor can call the operator and ask him to start the machine as soon the part is inspected	600	900
38			✓		External	Bring while machine is running or while setup is done (Parallel activity)	0	300
39							12	0

Some of the improvement suggestions includes

1. Maintaining 5S so the time in searching for the tool is saved. For maintaining 5S tool trolley was made. Fig. 11. shows the tool trolley.

Fig- 11: Tool Trolley

2. Parallel activities performed by the operator while the supervisor is doing the setup.

3. Rearranging the activities after setup which are not required during the setup like cleaning of the last setup tool, filling the setup sheet, filling the tool life monitoring sheet.

4. Further the time required to search the data on control sheet is eliminated by having a document that only includes the parameters which needs to be feed to the machine.

Similarly, by using the above steps and improvement ideas setup time can be reduced for 8 other machines. The following table shows the time reduced for the other 8 machines.

Table- 4: Reduction in Setup time machine wise

Machine Name	Operation	Time Before SMED (min)	Time After SMED (min)	Reduction in Time (min)	% Reduction in Setup Time
LS-150	Shaping	75	39	36	48%
SN4	Shaping	112	53	59	53%
MHI 1	Hobbing	76	29	47	62%
MHI 2	Hobbing	76	28	48	63%
LS-153	Hobbing	99	40	59	60%
PHA-250	Hobbing	100	41	59	59%
Hurth 1	Shaving	103	51	52	50%
Hurth 2	Shaving	101	53	48	48%
Hurth 3	Shaving	92	54	38	41%

5. RESULT

By implementing the above techniques, the total output capacity of the production line was increased from 1100 quantity per part to 1600. The back tracking and mixing of the material was eliminated. Manpower was reduced from 10 to 8 in Soft cell and 8 to 6 in Hard cell. Setup time was reduced by 41 to 63%.

6. CONCLUSION

By using the above mentioned tools the output capacity was increased. The changeover time and manpower was reduced. Thus helping the organization to make a sells of extra 1528985.7 INR. per month.

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