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ENHANCING OVERALL EQUIPMENT EFFECTIVENESS OF POWDER COATING MACHINE IN CONSTRUCTION EQUIPMENT MANUFACTURING INDUSTRY BY IMPLEMENTING LEAN TOOLS

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Abstract

This paper is based on enhancing the productivity of paint shop through overall equipment effectiveness with the help of lean manufacturing tool in construction equipment industry. The construction equipment industry is specialize in producing Backhoe Loaders, Smart Loaders, and Skid Steers etc. In today's competitive environment the most recommended things in an organization is quality and efficiency. These two parameters depends upon the utilization of equipment in the industry. It is very much important for an organization to keep track of, and improve the production performance of their production systems. Some of the production failures are improper maintenance, machine breakdown, non-availability of items, equipment performance, part rejections etc. Lean manufacturing tool identifies the waste and eliminate it from the manufacturing processes. Overall equipment effectiveness calculation is one of the way to improve the performance. The project has been addressed in three situations namely Availability, Performance, Quality which quantifies the OEE. The investigation result shows that the Overall Equipment Effectiveness has been improved.

Keywords: Construction Equipment Industry, Availability, Performance, Quality, Overall Equipment Effectiveness, Lean Manufacturing.

1. INTRODUCTION

In today's scenario the manufacturing industries uses OEE as an important key factor to monitor and control their performance effectiveness. The level of competition between the organizations is goes on increasing and customer demands become more accurate so that companies have ability to adapt these needs are protruding. Maintenance plays the important role in an industry. It keeps the machineries and equipment's accurate and efficient. So that it able to produce components with high quality and quantity and delivers at the right time according to the customer needs. OEE is the standard for measuring the productivity and it is used in Total Productive Maintenance (TPM) to point out how efficiently the machines are working. Proper implementation of lean tools helps to solve the problem effectively and results increase in productivity. This paper discusses about the existing OEE of paint shop and implementation of lean tools for improving OEE in paint shop.

2. PROBLEM DESCRIPTION

The problem described in this paper is taken from the industrial case. Here the purpose of paint shop is to on time deliver materials to assembly unit ensuring prescribed quality and quantity. But currently the paint shop is delivering products at the rate of 85.25 %. Our scope is to identify the causes of losses and minimize the deviation by implementing lean tools, same data is to be verified by comparing it with before & after OEE.

3. LITERATURE REVIEW

Hari Supriyanto and Mokh Suef (2018) have said that lean six sigma approach is used to improve facility performance in manufacturing companies. The goal is to identify, analyze and minimize all types of waste and maximize the value of OEE. This paper has introduced a combined OEE concept with LSS. Which is useful for analysis and measurement which can provide focus and benchmarks to provide a competitive advantage and continuous improvement through more effective resource utilization.

Siddharth S. Ghosh and Dr. M. M. Gupta (2016) stated in their study that bending machine and welding machine were identified as critical machines by means of grading of machines. Grading of machines was done on the basis of frequency of operation, volume of operation, failure, availability of alternatives and cost factor. Then the existing OEE of the machines are measured and concluded that both the critical machines have scope for improvement in OEE because the existing levels are lesser than that of world class OEE levels.

Amir Azizi (2015) has said that the study is focused on evaluation improvement of production productivity performance. The implementation of SPC (statistical process control), OEE (Overall equipment effectiveness) and (Autonomous maintenance) have minimized the defect rates of chipping and maximize the brushing machine performance, which improves the production effectiveness performance. SPC could identify and control the defection rate of tiles in glazing process. OEE could measure the machine performance by identifying the loss mechanism of machine. AM was able to practice in seeking for higher machine performance which aims to yield a higher production productivity performance. Thus production productivity performance has been increased by implementing AM and reducing the defect rate. The integration of SPC, OEE and AM is strongly recommended to improve production productivity performance of manufacturing industry.

Ramesh C.G and Mohammedasif Mulla (2014) have stated that they have implemented TPM & 5S techniques to improve the Availability, Performance & Quality of the machines. Though TPM, 5S technique and design of multi fixture were focused the availability and performance were improved significantly by minimizing equipment deterioration and failure. After implementation of TPM, 5S techniques and design of multi fixture the OEE has been increased.

M. VivekPrabhu, R. Karthick and Dr. G. Senthil Kumar (2014) have stated that OEE is an important performance measure for effectiveness of any equipment. The analysis should be done carefully to know the effect of various components. An attempt has been done in their study to optimize the OEE by using Genetic Algorithm and the study indicates that OEE will be improved if focus is given on performance rate improvement.

S.R. Vijayakumar and S. Gajendran (2014) have suggested in their study, the organization should introduce a maintenance system to improve and increase both the quality and productivity continuously. OEE is one of the performance evaluation methods that are most common and popular in the production industries. The Overall equipment effectiveness was improved with low machine breakdown, less idling and minor stops time, less quality defects, reduced accident in plant, increased the productivity rate, optimized process parameters, worker involvement, improved profits through cost saving method, increased customer satisfaction and increasing sales. In their work OEE of the injection molding process was increased through implementation of availability, better utilization of resources, high quality products and also raised employee morale and confidence.

E. Sivaselvam and S. Gajendran (2014) have stated that all industries are in the situation to improve their productivity. Every company is facing many challenging problems to produce better production rate. Manufacturers should be able to identify even the small factor affecting production growth. Clear identification of problem at the right time will help to increase quality as well as productivity rate. OEE is a known method to measure performance of production equipment in manufacturing.

V. Palanisamy and Jose Ananth Vino (2013) have stated that OEE is a measure of overall efficiency of an organization and it has a direct impact on company's bottom line. Usage of preventive maintenance reduces the downtime, skilled persons can be used to minimize reduced speed and small stops and implementation of SMED (single minute exchange of die) reduces the setup time of the machine. A greater ROI can expect by improving OEE. It is a very effective tool of comparison within plant, at different sites and also against competitors.

Binoy Boban and Jenson Joseph E (2013) have suggested in their study that, in the current scenario competition among industries are high. TPM may be the only thing that stands between success and total failure for some industries. TPM can be adapted to work not only in industrial plants, also in construction, building maintenance, transportation, and in variety of other situations. If everyone involved in a TPM program does his part, a usually high rate of return compared to resources invested may be expected. TPM success requires strong and active support from management, clear organization goals and objectives for TPM implementation.

Amit Kumar Gupta and Dr. R. K. Garg (2012) have mentioned in their study the effectiveness and implementation of TPM program in an automobile manufacturing organization. Thus TPM implementation in an automobile manufacturing organization increases the efficiency and productivity of broaching, cylindrical grinder and surface grinder machines.

F Castro and FAraujo (2012) identified how to reduce wastes and assuring compliance production process as key variable in the beverage industry. They applied OEE in the plant production line which fills beverage in bottles.

Nguyen Truong Son and Salwa Hanim Abdul Rashid (2011) demonstrates two very effective tools for improving productivity those are Value stream mapping (VSM) and Overall equipment effectiveness (OEE). Using VSM helps the manager to see the current situation and realize the existing waste in the factory and also help to imagine the effect of implementation of lean tool. OEE is used to identify and eliminate the losses. Therefore using both VSM and OEE is believed to achieve higher productivity than using alone.

4. OBJECTIVES

- To reduce the non-value added activities and lead time in paint shop.
- To improve the OEE of paint shop.
- To deliver materials at right quality & quantity to assembly unit.
- To improve operator skill.

5. OVERALL EQUIPMENT EFFECTIVENESS

Fig. 1. Components of OEE

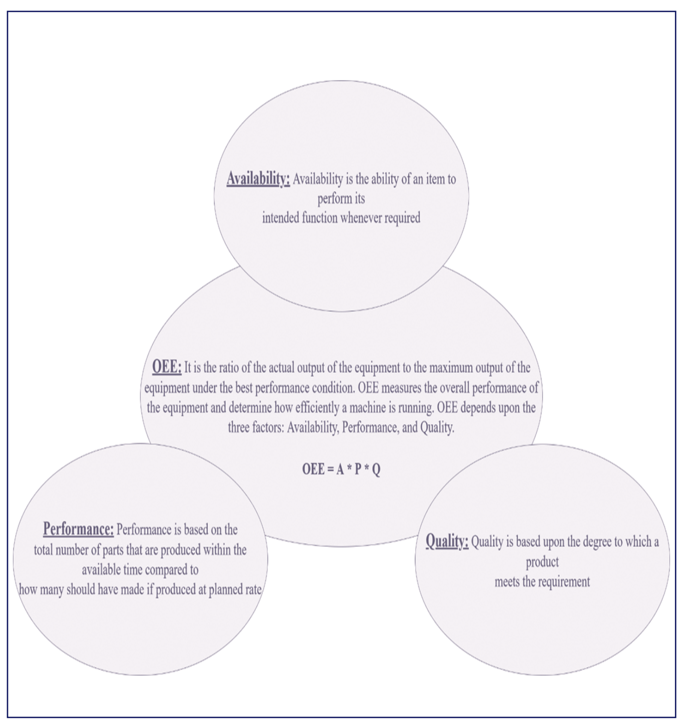
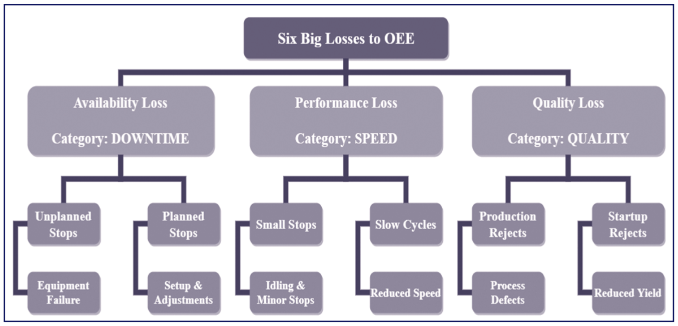


Fig. 2. Losses to OEE



5.1. OEE Calculation Method

The below table 1 shows the formula for calculating OEE.

Table 1. Formula for calculating OEE

Planned Downtime	Break time + Meal time + Cleaning time + Meeting time + Setup time
Unplanned Downtime	Mechanical breakdown + Electrical breakdown + Electrical breakdown
Good Parts	Total production parts – Total rework parts
Planned Production Time	Plant operating time – Planned downtime
Operating Time	Planned production time – Unplanned downtime
Availability	(Operating time / Planned production time) * 100
Performance	((Total production parts / Operating time) / Ideal run rate) * 100
Quality	(Good parts / Total production parts) * 100
OEE	Availability * Performance * Quality

5.2. Existing OEE Data and Analysis

The powder coating plant is operating 2 shifts per day. Each shift is having different types of planned downtime like break time, meal time, cleaning time, meeting time and loading time. The shift timings, planned downtimes of powder coating is shown in table 2.

Table 2. Paint shop data

Plant Operating Time	1st shift = 8:00 to 16:30	16hrs * 60min	960 min/day
	2nd shift = 16:30 to 12:00		
	Shift length * 60min		
Planned Downtime	Break time	Tea break 1st shift = 30min	60 min / day
		Tea break 2nd shift = 30min	
	Meal time	Lunch = 30 min	60 min / day
		Dinner = 30 min	
	Cleaning time		30 min
	Meeting time		10 min
	Loading time		4 min / frame

The table 3 shows powder coating machine production data's for 1month before implementation of lean tool. Thus by using one month production data's and formula's mentioned in table 1 the planned downtime, unplanned downtime, good parts, planned production time, operating time, factors of OEE such as Availability, Performance, Quality and OEE were calculated.

Table 3. Before powder coating machine OEE data

Production data / week	Week 1	Week 2	Week 3	Week 4	Total / overall
Total production parts (nos)	3250	3650	3500	3240	13640
Total rework parts (nos)	69	47	89	74	279
Good parts (nos)	3181	3603	3411	3166	13361
Planned downtime (min)	1800	1920	1680	2160	7560
Unplanned downtime (min)	718	602	693	568	2581
Ideal run rate / min	2	2	2	2	2
Planned production time (min)	3960	3840	4080	3600	15480
Operating time (min)	3242	3238	3387	3032	12899
Availability (%)	81.86	84.32	83.01	84.22	83.35
Performance (%)	50.12	56.36	51.66	53.43	52.89
Quality (%)	97.87	98.71	97.45	97.71	97.93
OEE (%)	40.15	46.90	41.78	43.96	43.19

Thus based on data calculated in table 3 the before percentage achievement of Availability, Performance, Quality, OEE and production actual vs target for four weeks is shown in fig 3 and 4.

Fig. 3. OEE Chart

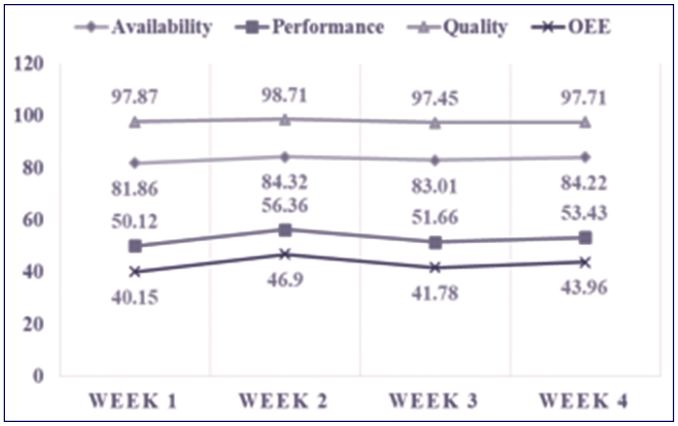


Fig. 4. Production Chart (Actual vs Target)

Based on unplanned downtime tracked the % occurrence of each downtime in availability loss is shown in fig 5 pie chart and the 80% of losses which cause powder coating machine to be idle is shown in fig 6 pareto chart for availability loss.

Fig. 5. Pie Chart (Availability loss)

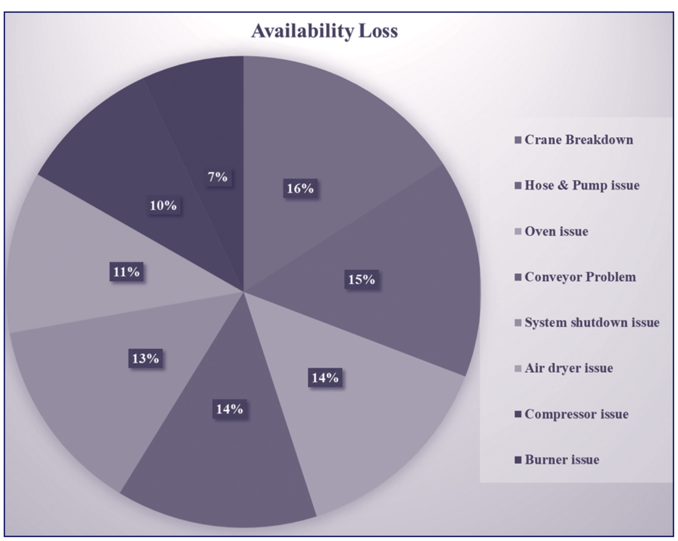
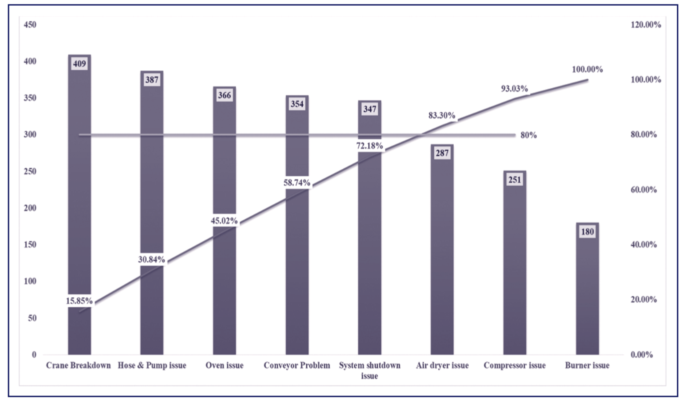


Fig. 6. Pareto Chart (Availability loss)



Based on rework of parts done the % occurrence of each quality loss is shown in fig 7 pie chart and the quality losses which occur 80% and above can be identified from fig 8 pareto chart for quality loss. Thus the parts with different quality related defects is shown in fig from 9 to 12.

Fig. 7. Pie Chart (Quality loss)

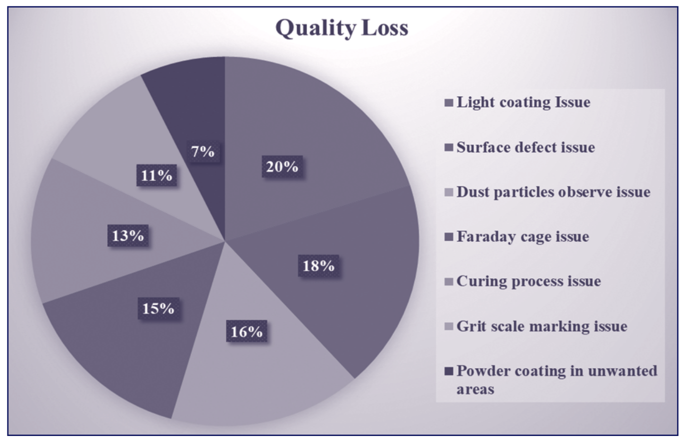


Fig. 8. Pareto Chart (Quality loss)

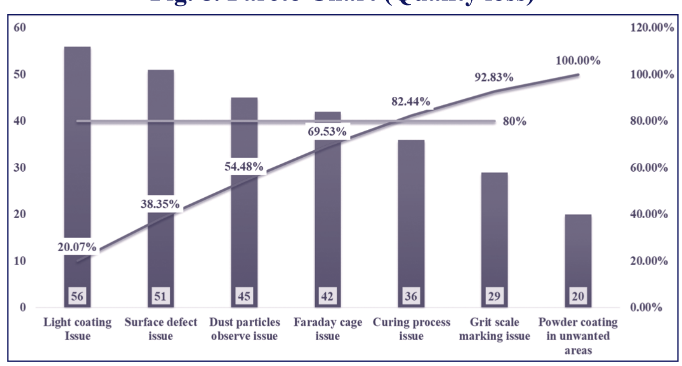


Fig. 9. Faraday Cage issue

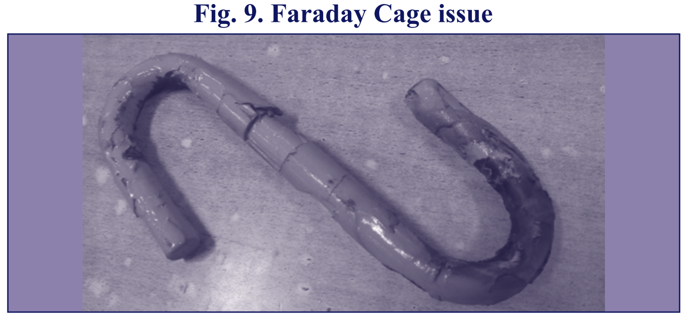


Fig. 10. Grit Scale marking & Improper powder coating issue

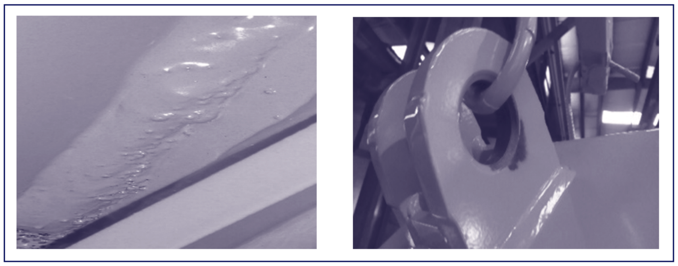


Fig.11. Light Coating issue

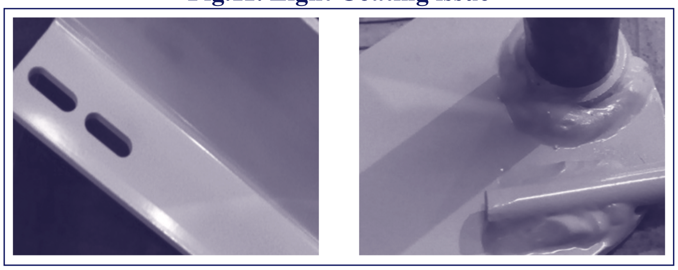


Fig. 12. Surface defect issues

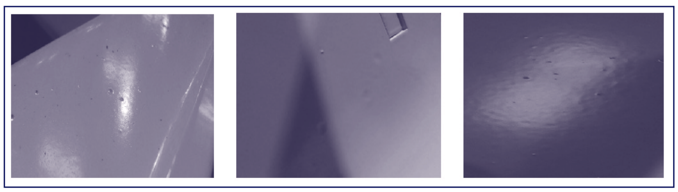
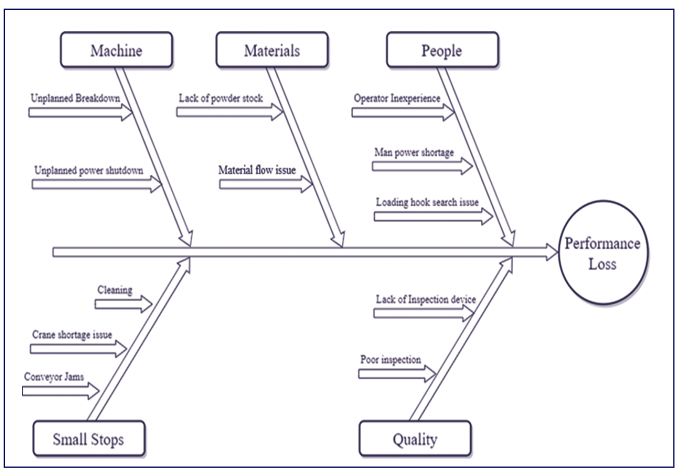


Fig. 13. Performance loss (CE Diagram)



The fig 13 shows the various performance losses occurred in powder coating. The main performance loss for powder coating is because of uneven material flow from the profile cutting process. The uneven material flow occurs due to underutilization of CNC profile cutting machines because of this underutilization it makes the profile cutting components for certain machines to be supplied to powder coating by outsourcing. So thereby it increases the lead time for material supplying to powder coating and increases outsource cost of profile cutting. Transferring of profile cutting components to the downstream process through wooden bins also leads to lag in supplying right products at right quantity in right time to right place. Thus to solve above said performance related issue the lean activities like optimal capacity utilization of profile cutting machines, JIT concept (pull system) and poka – yoke equipped bins should enable in the process.

6. IMPLEMENTATION OF LEAN TOOL

6.1. CNC Profile Cutting Machines Program Standardization – To deliver AGL – 6 nos / day, V3 FEL – 6 nos / day, All which include structure and implements: Based on the existing OEE data & Analysis we have observed the present pre fab and its subsequent process like CNC cutting, Child parts line feeding is developing uneven production flow to the downstream plant process as a result we unable to achieve the planned capacity which is targeted. Thus by analyzing current nesting format of CNC cutting process like LASER, MESSER & ZINSER it shows that they are utilizing one full nesting for one component profile. Due to this nesting format it leads to operate with more no of CNC programs, more time for supplying the component to the downstream process and it is not leading us to attain optimal usage of in house CNC machines within its available time. So in order to achieve our target we are outsourcing some of the CNC profile cutting programs. Thus it increases the lead time and outsourcing cost. In order to overcome the bottleneck we should standardize the CNC programs for LASER, MESSER & ZINSER machine. The standardization of CNC program is done by optimal utilization of one full nesting for multiple component profiles with same thickness. Once standardizing of CNC program is done the no of programs for CNC profile cutting process gets reduced. The standard programs and nesting utilization before vs after shown in fig 14, 16, and 17.

Fig. 14. Standard program chart

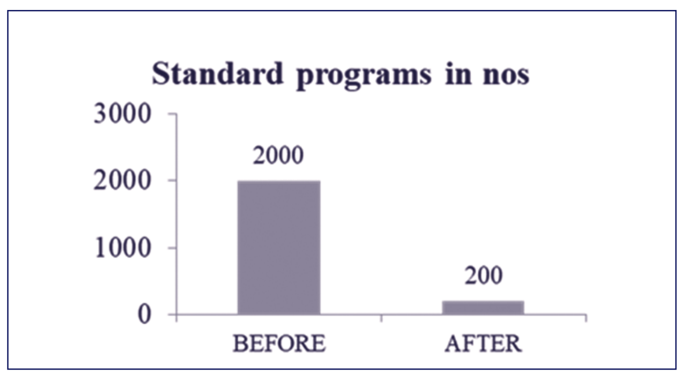


Fig. 15. Laser outsource cost Before vs After

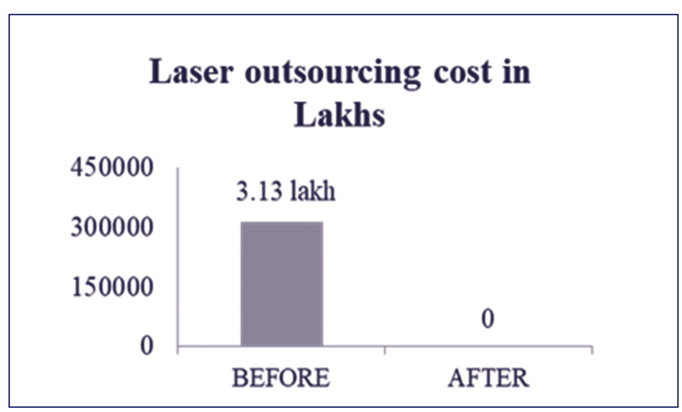


Fig. 16. Before nesting utilization

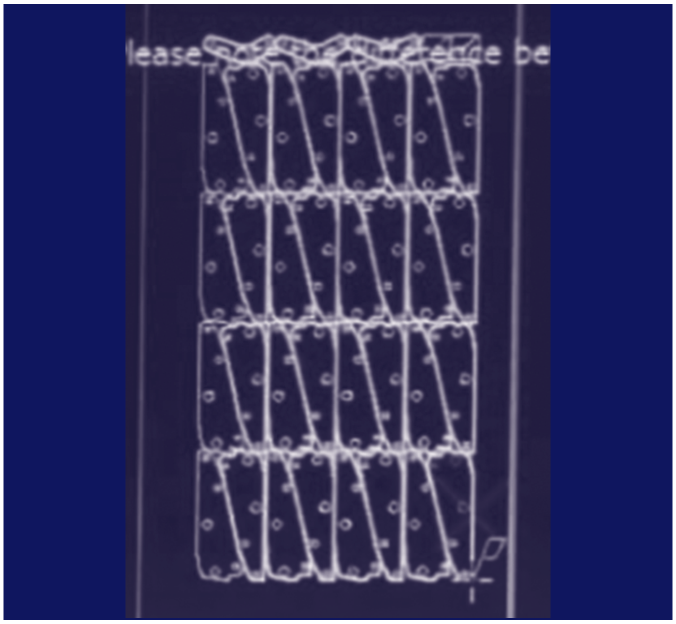
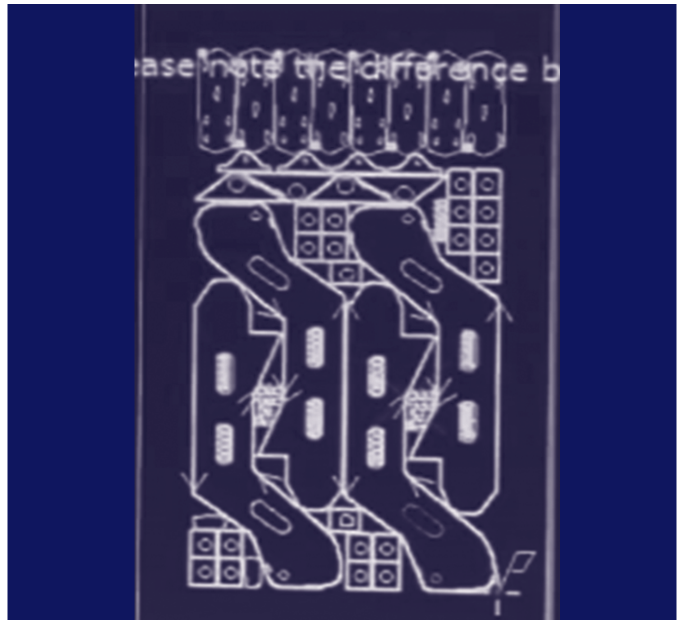


Fig. 17. After nesting utilization



Then according to the machines manufacturing ability regarding to thickness the standard programs have been allocated to respective machines. Once the standard programs are allotted to the respective machines thereby line balancing technique is carried out to check the in house capacity of CNC profile cutting machines. Based on line balancing performed in LEDAN LASER, MESSER, ZINSER CNC profile cutting machine we have arrived that the in house CNC profile cutting machines having the capacity to operate 49 nos of standard program for delivering 24 machines in 2 days.

The analyzing result shown in fig 18 suggests that no need to outsource the CNC programs of laser. So the lead time for material supplying to powder coating gets reduce & outsourcing cost of laser gets eliminated. The outsourcing cost of laser before vs after is shown in fig 15. The CNC MESSER, ZINSER having extra available time to produce additional 4 no's of machine in MESSER for one day and 3 no's of machine in ZINSER for one day.

Fig. 18. Machines capacity based on the standard program developed

Machines Capacity

Ledan CNC Laser cutting Machine

Total available time in 2 days = **2760 mins** ⟶ (1380x2)

Current average profile cutting time (for allocated standard programs) for 24 machines in 2 days = **2748 mins**

Average cycle time for 1 machine = **114 mins** ⟶ (2748/24)

Maximum machine capacity for 2 days = $\frac{\text{Total availabe time}}{\text{Average cycle time for 1 machine}} = \frac{2760}{114}$

Maximum machine capacity for 2 days = 24 machines

Therefore, Maximum machine capacity for 1 day = 12 machines

Messer CNC Profile cutting Machine

Total available time in 2 days = **2760 mins** ⟶ (1380x2)

Current average profile cutting time (for allocated standard programs) for 24 machines in 2 days = **2030 mins**

Average cycle time for 1 machine = **85 mins** ⟶ (2030/24)

Maximum machine capacity for 2 days = $\frac{\text{Total availabe time}}{\text{Average cycle time for 1 machine}} = \frac{2760}{85}$

Maximum machine capacity for 2 days = 32 machines

Therefore, Maximum machine capacity for 1 day = 16 machines

Zinser CNC Profile cutting Machine

Total available time in 2 days = 2760 mins ⟶ (1380x2)

Current average profile cutting time (for allocated standard programs) for 24 machines in 2 days = **2176 mins**

Average cycle time for 1 machine = **91 mins** ⟶ (2176/24)

$$\text{Maximum machine capacity for 2 days} = \frac{\textit{Total availabe time}}{\textit{Average cycle time for 1 machine}} = \frac{2760}{91}$$

Maximum machine capacity for 2 days = 30 machines

Therefore, Maximum machine capacity for 1 day = 15 machines

6.2. Standard Bin and Layout

Once we supply the profile cutting components to the downstream process there is also lag in supplying right products at right quantity in right time to right place. This lag happens because they are supplying the profile cutting components to downstream process with wooden bins shown in fig 22 and placing the bins at different factory locations shown in fig 19. Due to placing the bins in undefined location it increases the searching time to find out the right product and losing of components gets happen because of usage of wooden bins. The wooden bins does not have the defined quantity to store the component and no fool proofing system is enabled in it. So the production flow to downstream process gets uneven.

Fig. 19. Child parts placing at different factory locations

In order to supply right products at right quantity in right time to right place we should establish the 3 bin system Thus 1st set bin will be near profile cutting machine layout as shown in fig 21, 2nd bin set will be in centralized PPC supermarket to accommodate the standard bin under one location, 3rd set bin will be in welding work center. So that we can avoid placing of bins in undefined locations. Each standard line feeding bins will have the right capacity to accommodate the components and will enable with fool proofing system (POKA – YOKE) as shown in fig 23 and 24. Thus by adopting the standard line feeding bin system with centralized PPC supermarket shown in fig 23 and 25 the above said issues can be avoided. So we can make the production flow even to the downstream process there by it enhances the efficiency of the system. The layout of shop floor before vs after and layout implementation is shown in fig from 20 and 21.

Fig. 20. Before layout implementation

Fig. 21. After layout implementation

Fig. 22. Wooden bin setup

Fig. 23. Poka – yoke bins

Fig. 24. Standard bin fabrication & Bin with child parts loaded setup

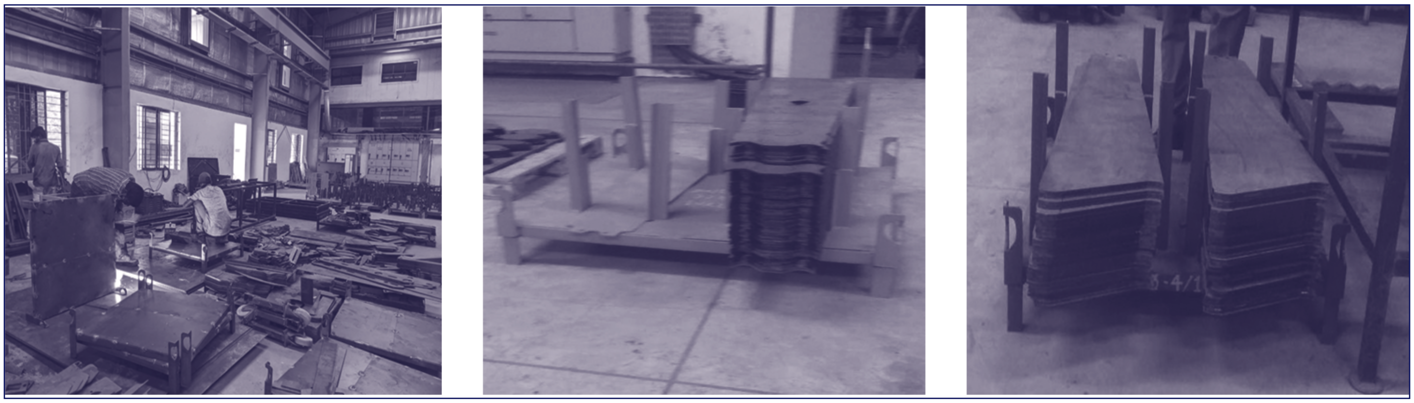
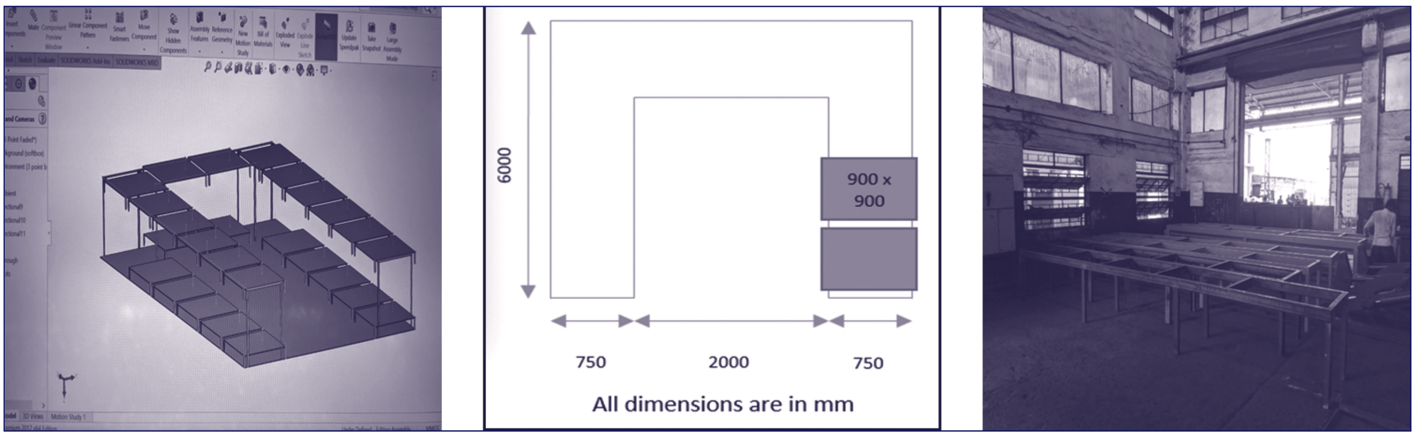


Fig. 25. Centralized PPC frame design & Frame Fabricated



7. AFTER OEE DATA OF POWDER COATING MACHINE

The table 4 shows powder coating machine production data's for 1month after implementation of lean tool. Thus by using one month production data's and formula's mentioned in table 1 the planned downtime, unplanned downtime, good parts, planned production time, operating time, factors of OEE such as Availability, Performance, Quality and OEE were calculated. The result shows that after implementing lean tools like JIT concept & optimal machine capacity utilization the overall equipment effectiveness of powder coating machine had improved.

Table 4. After powder coating machine OEE data

Production data / Week	Week 1	Week 2	Week 3	Week 4	Total / Overall
Total Production Parts (Nos)	4000	4000	4000	4000	16000
Total Rework Parts (Nos)	37	23	42	31	133
Good Parts (Nos)	3963	3977	3958	3969	15867
Planned Downtime (Min)	1800	1920	1680	2160	7560
Unplanned Downtime (Min)	407	252	377	298	1334
Ideal Run Rate / Min	2	2	2	2	2
Planned Production Time (Min)	3960	3840	4080	3600	15480
Operating Time (Min)	3553	3588	3703	3302	14146
Availability (%)	89.72	93.43	90.75	91.72	91.40
Performance (%)	56.29	55.74	54.01	60.56	56.65
Quality (%)	99.07	99.42	98.95	99.22	99.16
OEE (%)	50.03	51.77	48.49	55.11	51.35

8. BEFORE & AFTER RESULT COMPARISON

This work was aimed to make improvement on production performance of powder coating machine. A construction equipment manufacturing industry's powder coating machine has been considered for this study. The implementation of Just in time concept (poka – yoke equipped 3 standard bins system) and Optimal capacity utilization of profile cutting machines has been done by redesigning the CNC programs according to daily requirements of child parts should be delivered to the powder coating machine. The result shows that above implementation of lean tools have minimized the lead time of child parts supplying from profile cutting machine to powder coating machine as 5 days to 3 days, eliminates the outsourcing cost of child parts from Rs. 313000 lakh per month to Rs. 0 by redesigning of CNC programs. Due to this arrival of parts from profile cutting to powder coating machine becomes even and increases production performance of powder coating machine from 13640 nos to 16000nos per month. Thereby OEE of powder coating machine increases from 43.19 % to 51.35 %. The before and after result comparison of powder coating machine is shown in table 5

Table 5. Before & After result comparison

S.NO	PARAMETERS	BEFORE	AFTER
1	Outsourcing cost	₹ 313000 per month	₹ 0 per month
2	Per month OEE (%)	43.19	51.35
3	Per month production parts (Nos)	13640	16000
4	Lead time (Days)	5	3
5	Outsource cost saving	₹ 3756000 per annum	

9. GAP ANALYSIS

9.1. Ledan Laser Cutting Standard Program Summary to Produce 48 Machines in 2 Days **Figure 26 shows the standard program allocated for ledan laser cutting machine.**

Figure 26 Allocated standard program for ledan laser cutting machine to produce 48 machines in 2 days

Sl.no	Thickness	Length	Width	Program NO	STANDARD PROGRAM NAME	One Plate Nesting QTY	Total Cutting Time in Mint	FINAL
1	1.6	2500	1250	AGL-1	AGRI_BULL_LOADER_1.6MMCR_12MC	12	11.88325	23.7665
2	5	2500	1250	AGL-2	AGRI_BULL_LOADER_5MMCR_1.5MC	1.5	26.25966667	420.1546667
3	5	3000	1500	AGL-3	AGRI_BULL_LOADER_5MMHR_12MC	12	49.01366667	98.02733333
4	6	3050	1500	AGL-4	AGRI_BULL_LOADER_6MM_24MC	24	46.94607143	46.94607143
5	8	3000	1500	AGL-5	AGRI_BULL_LOADER-8MM-24MC	24	113.0354167	113.0354167
6	10	3000	1500	AGL-6	AGL_LOADER_10MM_6MC	6	129.3561905	517.4247619
7	12	3000	1500	AGL-7	AGL_LOADER_12MM_24MC	24	389.495	389.495
8	1.6	2500	1250	V3-FEL-1	V3_FEL_LOADER_1.6MMCR_12MC	12	11.88325	23.7665
9	5	2500	1250	V3-FEL-2	V3_FEL_LOADER_5MMCR_1MC	1	16.60866667	398.608
10	6	2700	1500	V3-FEL-3	V3_FEL_LOADER_6MM_12MC	12	55.685	111.37
11	8	3050	1500	V3-FEL-4	V3_FEL_LOADER-8MM-6MC	6	103.8795833	415.5183333
12	3	1250	1510	AGL BKT-1	AGRI_LOADER_BKT_3MMCR_6MC	6	11.13233333	44.52933333
13	4	2500	1500	AGL BKT-2	AGRI_LOADER_BKT_4MM_2MC	2	9.648285714	115.7794286
14	5	2500	1500	AGL BKT-3	AGRI_LOADER_BKT_4MM_4MC	4	16.03790476	96.22742857
15	5	3000	1500	AGL BKT-4	AGRI_LOADER_BKT_5MMHR_12MC	12	71.84433333	143.6886667
16	8	3000	1500	AGL BKT-5	AGRI_BULL_LOADER_BKT-8MM-15MC	15	79.310625	158.62125
17	10	3000	1500	AGL BKT-6	AGRI_BULL_LOADER_BKT-10MM-10MC	10	95.31333333	285.94
18	12	1600	1500	AGL BKT-7	AGRI_BULL_LOADER_BKT-12MM-5MC	5	63.26	316.3
19	2	2500	1250	V3FEL_BBKT_1	V3FEL_BBKT_0.75_2MM_22MC	22	12.63916667	25.27833333
20	3	500	1500	V3FEL_BBKT_2	V3FEL_BBKT_0.75_3MM_5MC	5	3.482857143	17.41428571
21	4	2500	1250	V3FEL_BBKT_3	V3FEL_BBKT_0.75_4MM_2MC	2	9.374333333	112.492
22	4	2500	1250	V3FEL_BBKT_4	V3FEL_BBKT_0.75_4MM_1MC	1	6.674666667	160.192
23	4	2500	1250	V3FEL_BBKT_5	V3FEL_BBKT_0.75_4MM_4MC	4	10.56133333	63.368
24	5	1700	1500	V3FEL_BBKT_6	V3FEL_BBKT_0.75_5MM_12MC	12	51.8	103.6
25	8	2800	1500	V3FEL_BBKT_7	V3FEL_BBKT_0.75_8MM_8MC	8	43.19916667	129.5975
26	10	3000	1500	V3FEL_BBKT_8	V3FEL_BBKT_0.75_10MM_5MC	5	68.60642857	343.0321429
							TOTAL	4674.172952

TOTAL 4674.172952

For 1 day the available time is 1440 minutes. Then for 2 days the available time is 1440 * 2 = 2880 minutes. The planned downtime for ledan laser cutting machine is lunch time. The industry is operating 2 shifts per day for each shift the lunch time allocated is 30 minutes. Then for 2 days the lunch time is 120 minutes. By subtracting Available time – Planned downtime = (2880 – 120) = the machine available time for 2 days is 2760 minutes but our allocated 26 standard program for ledan laser cutting machine operates 4674 minutes. Thus the inhouse single ledan laser cutting machine is not enough to manufacture 48 machines in 2 days because of additional cycle time 1914 minutes is require for 2 days shown in fig 28. Additional cycle time is the difference between (Total cutting cycle time – Ledan laser available time = 4674 – 2760 = 1914 minutes). So the following programs shown in figure 27 should either outsource or another CNC laser cutting machine should install in the inhouse by considering the outsource cost. The capacity utilization of Ledan laser cutting machine is shown in fig 28.

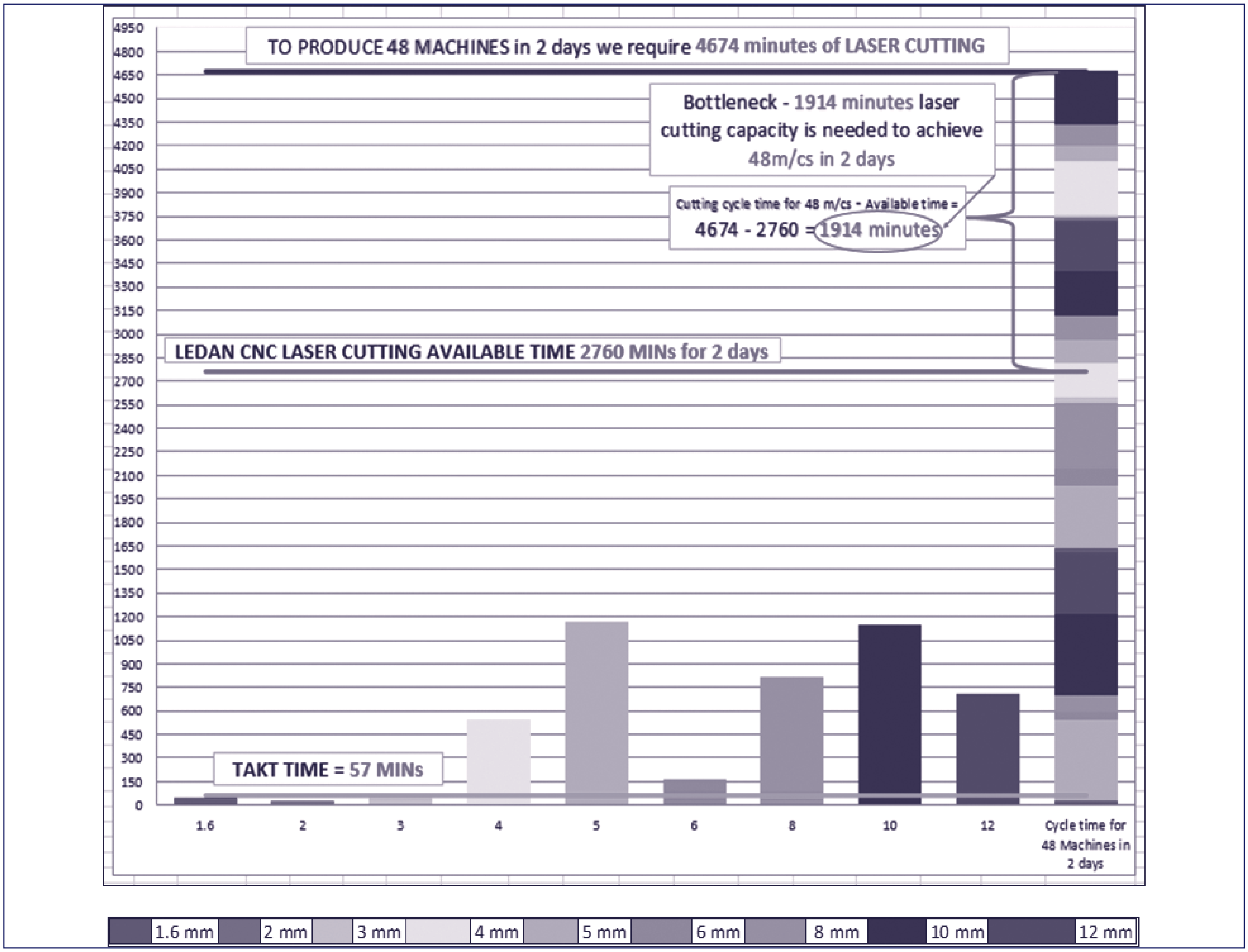
Figure 27 Outsource standard programs of laser cutting

	Plate Thickness in mm						
Standard program name	1.6	2	3	4	5	Cycle time for 48 Machines in 2 days	Cutting Cost for 2 days
AGRI_BULL_LOADER_1.6MMCR_12MC	23.7665					23.77	713.00
AGRI_BULL_LOADER_5MMCR_1.5MC					420.155	420.15	12604.64
AGRI_BULL_LOADER_5MMHR_12MC					98.0273	98.03	2940.82
V3_FEL_LOADER_1.6MMCR_12MC	23.7665					23.77	713.00
V3_FEL_LOADER_5MMCR_1MC					398.608	398.61	11958.24
AGRI_LOADER_BKT_3MMCR_6MC			44.529			44.53	1335.88
AGRI_LOADER_BKT_4MM_2MC				115.78		115.78	3473.38
AGRI_LOADER_BKT_4MM_4MC				96.227		96.23	2886.82
AGRI_LOADER_BKT_5MMHR_12MC					143.689	143.69	4310.66
V3FEL_BBKT_0.75_2MM_22MC		25.27833				25.28	758.35
V3FEL_BBKT_0.75_3MM_5MC			17.414			17.41	522.43
V3FEL_BBKT_0.75_4MM_2MC				112.49		112.49	3374.76
V3FEL_BBKT_0.75_4MM_1MC				160.19		160.19	4805.76
V3FEL_BBKT_0.75_4MM_4MC				63.368		63.37	1901.04
V3FEL_BBKT_0.75_5MM_12MC					103.6	103.60	3108.00
	1846.89	1846.89	1846.89	1846.89	1846.89	**1846.89**	
Available production time	2760	2760	2760	2760	2760	2760	
Target load - TAKT TIME	57.5	57.5	57.5	57.5	57.5	57.5	
Total	47.533	25.27833	61.944	548.06	1164.08	1846.89	55406.77

The outsource cost for laser cutting is calculated as follows:

- Formula to calculate laser outsource cost = Total cycle time * Per min cutting cost
- Per minute outsource cutting charge for laser = Rs. 30
- Total minutes laser program should outsource to produce 48 machines in 2 days = 1846.89 mins
- 2 days Laser outsource cost to produce 48 machines in 2 days = 1846.89 * 30 = Rs. 55406.7
- Per day outsource cost = Outsource cost for 2 days / 2 = 55406.7 / 2 = Rs. 27703.35
- Per month laser outsource cost = Per day outsource cost * 26 days = 27703.35 * 26 = Rs. 720287
- Per year laser outsource cost = Per month outsource cost * 12 months = 720287 * 12 = Rs. 8643445

Figure 28 Gap analysis - Ledan laser cutting machine capacity utilization chart to produce 48 machines in 2 days



9.2. CNC Messer Cutting Standard Program Summary to Produce 48 Machines in 2 Days Figure 29 shows the standard program allocated for cnc messer cutting machine.

Figure 29 Allocated standard program for CNC messer cutting machine to produce 48 machines in 2 days

Sl.no	Thickness	Length	Width	Program NO	STANDARD PROGRAM NAME	One Plate Nesting QTY	Total Cutting Time in Mint	FINAL
1	20	1500	1100	MM575-AGL-5	MM575_AGL_20MM_6MC	6	145.9	584
2	10	2800	1500	V3-FEL-5	V3_FEL_LOADER_10MM_4MC	4	58.8	352.9
3	10	3050	1500	V3-FEL-6	V3_FEL_LOADER_10MM_6MC	6	138.6	554.446667
4	10	2300	1500	V3-FEL-7	V3_FEL_LOADER_10MM_6MC_A	6	102.6	410.566667
5	4	2400	1250	JD5310 4WD-1	JD5310_V3FEL_STRUC_4MM_6MC	6	80.8	323.2
6	6	3000	1500	JD5310 4WD-3	JD5310_V3FEL_STRUC_6MM_8MC	8	148.9	595.796923
7	16	350	1500	JD5310 4WD-6	JD5310_V3FEL_STRUC_16MM_6MC	6	125.3	501.2
8	20	1500	2500	JD5310 4WD-7	JD5310_V3FEL_STRUC_20MM_6MC	6	647.3	2589.2
9	25	2100	1500	V3-FEL-10	V3_FEL_LOADER_25MM_12MC	12	377.9	755.866667
10	50	1500	450	AGL-8	AGL_LOADER_50MM_24MC	24	142.2	284.4
							TOTAL	6951

The messer cutting machine is fitted with two flame cutting torches so it can double the productivity in single shift when compared to the machine with single torch. For 1 day the available time of 2 torch is 2880 minutes. Then for 2 days the available time is 2880 * 2 = 5760 minutes. The planned downtime for cnc messer cutting machine is lunch time. The industry is operating 2 shifts per day for each shift the lunch time allocated is 30 minutes. Then for 2 days the lunch time is 240 minutes. By subtracting Available time – Planned downtime = (5760 – 240) = the machine available time for 2 days is 5520 minutes but our allocated 10 standard program for cnc messer cutting machine operates 6951 minutes. Thus the inhouse single CNC messer cutting machine is not enough to manufacture 48 machines in 2 days because of additional cycle time 1431 minutes is require for 2 days shown in fig 31. Additional cycle time is the difference between (Total cutting cycle time – CNC messer available time = 6951 – 5520 = 1431 minutes). So the following programs shown in figure 30 should either outsource or another CNC messer cutting machine should install in the inhouse by considering the outsource cost. The capacity utilization of CNC messer cutting machine is shown in fig 31.

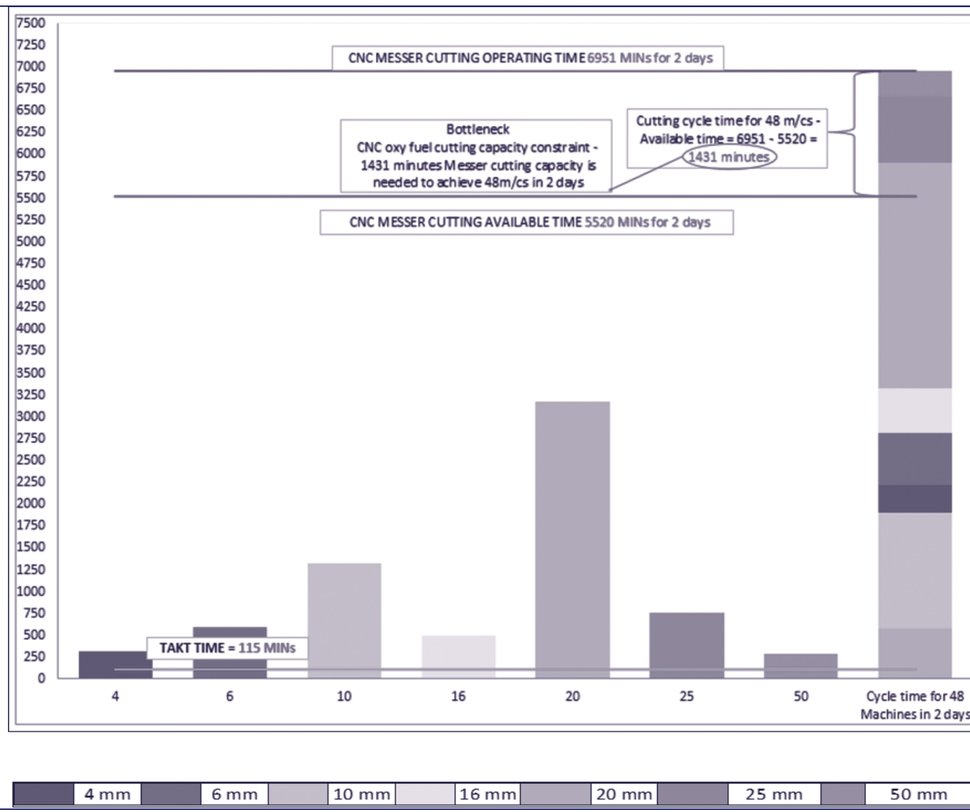
Figure 30 Outsource standard programs of messer cutting

Standard program name	10	Cycle time for 48 Machines in 2 days	Cutting cost for 2 days
V3_FEL_LOADER_10MM_4MC	352.9	352.90	11012.10
V3_FEL_LOADER_10MM_6MC	554.4466667	554.45	16607.14
V3_FEL_LOADER_10MM_6MC_A	410.5666667	410.57	12281.50
Available production time	5520	5520	
Target load - TAKT TIME	115	115	
	1317.91	1317.91	
Total	1317.913333	1317.91	39900.74

The outsource cost for flame cutting is calculated as follows:

- Formula to calculate cnc flame cutting cost = ((length of cut * thickness * 2.75) / 1000) * no of times program should run
- 2 days flame cutting outsource cost calculation for V3 FEL LOADER 10MM 4MC = ((33370 * 10 * 2.75) / 1000) * 12 = Rs. 11012.10
- 2 days flame cutting outsource cost calculation for V3 FEL LOADER 10MM 6MC = ((75487 * 10 * 2.75) / 1000) * 8 = Rs. 16607.14
- 2 days flame cutting outsource cost calculation for V3 FEL LOADER 10MM 6MC A = ((55825 * 10 * 2.75) / 1000) * 8 = Rs. 12281.5
- Total 2 days messer cutting outsource cost to produce 48 machines in 2 days = 11012.10 + 16607.14 + 12281.5 = Rs. 39900.74
- Per day outsource cost = Outsource cost for 2 days / 2 = 39900.74 / 2 = Rs. 19950.37
- Per month messer cutting outsource cost = Per day outsource cost * 26 days = 19950.37 * 26 = Rs. 518709.62
- Per year messer cutting outsource cost = Per month outsource cost * 12 months = 518709.62 * 12 = Rs. 6224515.44

Figure 31 Gap analysis – CNC messer cutting machine capacity utilization chart to produce 48 machines in 2days



9.3. CNC Zinser Cutting Standard Program Summary to Produce 48 Machines in 2 Days. Figure 32 shows the standard program allocated for cnc zinser cutting machine.

Figure 32 Allocated standard program for CNC zinser cutting machine to produce 48 machines in 2 days

Sl.no	Thickness	Length	Width	Program NO	Description	One Plate Nesting QTY	Total Cutting Time in Mint	FINAL
1	4	1250	1300	MM575-AGL-1	MM575_AGL_4MM_12MC	12	110.3	220.6
2	6	350	1500	MM575-AGL-2	MM575_AGL_6MM_15MC	15	28.3	56.6
3	12	300	1500	MM575-AGL-3	MM575_AGL_12MM_12MC	12	62.9	125.8
4	16	1500	900	MM575-AGL-4	MM575_AGL_16MM_12MC	12	193.1	386.2
5	25	1500	450	MM575-AGL-6	MM575_AGL_25MM_12MC	12	178.1	356.2
6	12	2500	1500	V3-FEL-8	V3_FEL_LOADER_12MM_24MC	24	380.585	380.585
7	20	2150	1500	V3-FEL-9	V3_FEL_LOADER_20MM_12MC	12	400.42	800.84
8	5	2200	1500	JD5310 4WD-2	JD5310_V3FEL_STRUC_5MM_12MC	12	31.2	62.4
9	10	700	1500	JD5310 4WD-4	JD5310_V3FEL_STRUC_10MM_12MC	12	89.7	179.4
10	12	210	1500	JD5310 4WD-5	JD5310_V3FEL_STRUC_12MM_24MC	24	77.3	77.3
11	25	1500	400	JD5310 4WD-8	JD5310_V3FEL_STRUC_25MM_12MC	12	184.3266667	368.653333
12	16	2400	1500	V3FEL_BBKT_9	V3FEL_BBKT_0.75_16MM_14MC	14	156.4733333	312.946667
13	20	1500	2500	V3FEL_BBKT_10	V3FEL_BBKT_0.75_20MM_12MC	12	282.7	565.4
							TOTAL	3892.925

For 1 day the available time is 1440 minutes. Then for 2 days the available time is 1440 * 2 = 2880 minutes. The planned downtime for cnc zinser cutting machine is lunch time. The industry is operating 2 shifts per day for each shift the lunch time allocated is 30 minutes. Then for 2 days the lunch time is 120 minutes. By subtracting Available time – Planned downtime = (2880 – 120) = the machine available time for 2 days is 2760 minutes but our allocated 13 standard program for cnc zinser cutting machine operates 3892 minutes. Thus the inhouse single zinser cutting machine is not enough to manufacture 48 machines in 2 days because of additional cycle time 1132 minutes is require for 2 days shown in fig 34. Additional cycle time is the difference between (Total cutting cycle time – Ledan laser available time = 3892 – 2760 = 1132 minutes). So the following programs shown in figure 33 should either outsource or if the new CNC messer cutting machine is bought the following programs can be shifted to the new inhouse CNC messer cutting machine in order to reduce the outsource cost of flame cutting. The capacity utilization of CNC zinser cutting machine is shown in fig 34.

Figure 33 Outsource standard programs of zinser cutting

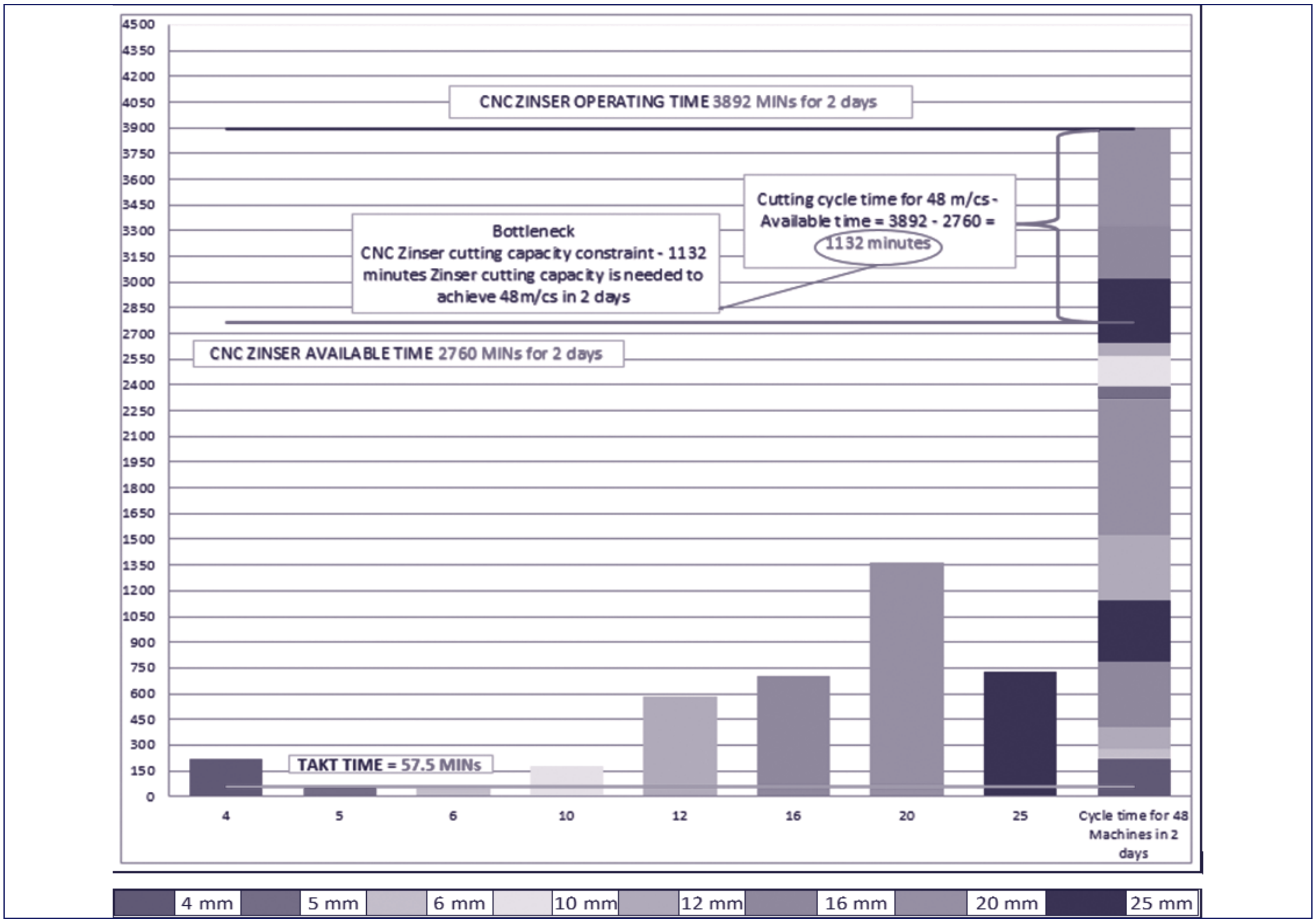
Standard program name	4	5	6	10	12	Cycle time for 48 Machines in 2 days	Cutting cost for 2 days
MM575_AGL_4MM_12MC	220.6					220.6	3191.45
MM575_AGL_6MM_15MC			56.6			56.6	1157.97
MM575_AGL_12MM_12MC					125.8	125.8	3077.18
V3_FEL_LOADER_12MM_24MC					380.585	380.585	7557.06
JD5310_V3FEL_STRUC_5MM_12MC		62.4				62.4	1093.23
JD5310_V3FEL_STRUC_10MM_12MC				179.4		179.4	5412.44
JD5310_V3FEL_STRUC_12MM_24MC					77.3	77.3	1634.55
Available production time	2760	2760	2760	2760	2760	2760	
Target load - TAKT TIME	57.5	57.5	57.5	57.5	57.5	57.5	
	1102.685	1102.685	1102.685	1102.685	1102.685	1102.685	
Total	220.6	62.4	56.6	179.4	583.685	1102.685	23123.88

The outsource cost for flame cutting is calculated as follows:

- Formula to calculate cnc flame cutting cost = ((length of cut * thickness * 2.75) / 1000) * no of times program should run
- 2 days flame cutting outsource cost calculation for MM 575 AGL 4MM 12 MC = ((72533 * 4 * 2.75) / 1000) * 4 = Rs. 3191.45
- 2 days flame cutting outsource cost calculation for MM 575 AGL 6MM 15 MC = ((17545 * 6 * 2.75) / 1000) * 4 = Rs. 1157.97
- 2 days flame cutting outsource cost calculation for MM 575 AGL 12MM 12MC = ((23312 * 12 * 2.75) / 1000) * 4 = Rs. 3077.18
- 2 days flame cutting outsource cost calculation for V3 FEL LOADER 12MM 24MC = ((114501 * 12 * 2.75) / 1000) * 2 = Rs. 7557.06

- 2 days flame cutting outsource cost calculation for JD5310 V3 FEL STRUCTURE 5MM 12MC = ((19877 * 5 * 2.75) / 1000) * 4 = Rs. 1093.23
- 2 days flame cutting outsource cost calculation for JD5310 V3 FEL STRUCTURE 10MM 12MC = ((49204 * 10 * 2.75) / 1000) * 4 = Rs. 5412.44
- 2 days flame cutting outsource cost calculation for JD5310 V3 FEL STRUCTURE 12MM 24MC = ((24766 * 12 * 2.75) / 1000) * 2 = Rs. 1634.55
- Total 2 days zinser cutting outsource cost to produce 48 machines in 2 days = 3191.45 + 1157.97 + 3077.18 + 7557.06 + 1093.23 + 5412.44 + 1634. 55 = Rs. 23123.88
- Per day outsource cost = Outsource cost for 2 days / 2 = 23123.88 / 2 = Rs. 11561.94
- Per month zinser cutting outsource cost = Per day outsource cost * 26 days = 11561.94 * 26 = Rs. 300610
- Per year zinser cutting outsource cost = Per month outsource cost * 12 months = 300610 * 12 = Rs. 3607325.28

Figure 34 Gap analysis – CNC zinser cutting machine capacity utilization chart to produce 48 machines in 2days



10. CONCLUSIONS

The Overall Equipment Effectiveness method is used to find out how effectively industries are utilizing equipment or plant. The Key Successful improvement of Overall Equipment Effectiveness (OEE) depends on the elimination of three OEE loss categories like Downtime Loss, Speed Loss and Quality Loss. To improve productivity it is essential to improve the performance of the manufacturing systems. The desired production output is achieved through high equipment availability, which is influenced by equipment reliability and maintainability. Overall equipment Effectiveness (OEE) is not a statistically valid metric, but it has been used widely over the years. Overall equipment Effectiveness (OEE) does not diagnose a specific reason why a machine is not running as efficiently as possible, but it helps to categorize the areas for initiating the equipment improvement. Overall Equipment effectiveness (OEE) is a structured continuous improvement process that strives to optimize production effectiveness by identifying and eliminating losses associated with equipment and production efficiency throughout the production system life cycle through active team - based involvement of employees across all levels of the operational hierarchy.

11. FUTURE SCOPE

As for future scope, the current rate of production is achieved our target value, therefore improvement is still needed because in future we are planning to do production 24 machines per day in profile cutting machine based on that we have analysed the in house capacity of profile cutting machines and the data's arrived are shown in section 9 (GAP ANALYSIS).

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