Chapter 14
Evaluation and Improvisation of Overall Equipment Effectiveness in a Sheet Metal Parts Manufacturing Industry

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Abstract This chapter presents a case study of evaluation and improvisation of Overall Equipment Effectiveness for the machines like CNC Laser Cutting and CNC Panel Bender present in a small-scale industry involved in the fabrication of steel furniture. The calculations and analysis of Overall Equipment Effectiveness for the machines are carried out by measuring the time required for various steps involved during the manufacturing of the parts and also through conversation, interrogation and observations over a period of one week. After the current status of Overall Equipment Effectiveness is known, the lean tools and techniques like Root cause analysis, Six Big Losses, Kaizen and Single Minute Exchange of Die was used. The Kaizen team was formed and was led for four days. Also, the suggestions were implemented with the assistance of the Kaizen team. After the implementation of the tools and techniques again Overall Equipment Effectiveness was calculated and it was found to have improved. Later, the scheduling of the CNC Laser Cutting and CNC Panel Bender was also carried out with the assistance of scheduling software "LEKIN" for further improvement of Overall Equipment Effectiveness.

Keywords Overall equipment effectiveness · Root cause analysis · Six big losses · Kaizen · Single minute exchange of die

14.1 Introduction

In any industrial sector, efficiency and effectiveness should be implemented so as to be increasingly beneficial. Manufacturing industries can possibly remain in a focused market if their manufacture facilities are available and productive. Thus maintenance has become a competitive weapon for any industry to survive in the

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competitive market. In the 1980s, the total productive maintenance (TPM) philosophy, propelled by Nakajima (1988), lead to a metric called Overall Equipment Effectiveness (OEE). Overall equipment effectiveness is a measurement tool used in identifying and measuring the productivity of machines in the industry [1]. The literature reveals that to determine OEE, no standard exists. It is very broad and can be applied to any manufacturing organization. It can be used to measure the efficiency of product lines, a section of the plant and even the entire plant. OEE is essentially the ratio of fully productive time to planned production time. In practice, however, OEE is calculated as the product of its three contributing factors [2]:

$$\text{OEE} = \text{Availability} \times \text{Performance} \times \text{Quality} \tag{14.1}$$

14.2 Brief About the Industry

This case study is carried out in a small-scale industry—Onkar Furnitech established in 1983 at Nagpur, Maharashtra. The company is engaged in manufacturing and supplying a wide range of Hospital Furniture, Panchakarma Equipment, Kitchen and Wardrobe and Bedside Lockers, etc. using optimum quality raw material and latest equipment. Machinery like CNC Laser Cutting, CNC Panel Bender, CNC Press Brake are the preceding machines that are operated by skilled workers whereas Spot welding, MIG welding, Bench Grinding, Hand Grinding, Power Press machine, Pipe Bending Machine and Drilling machine are also used. This case study mainly focuses on the CNC Laser Cutting machine and CNC Panel Bender machine.

14.3 Research Method

The research strategy is a case study which consists of interviews and observations. That is the reason that both qualitative and quantitative methods are used in the project. When interviews are conducted it is said to be a qualitative method whereas when the data is collected and analyzed it is said to be a quantitative method [3]. The author collected the data by time study method with the help of stopwatch and also received the data from the company employees. The motive of the data collection is explained to the workers involved in the information so that suitable and reliable data can be collected.

14.4 Details of Manufacturing Activities

The company is working in a single shift from 8:30 am to 5:00 pm. including a 30-min lunch break. It is a make to order based company that manufactures various customized products. The company works for six days in a week and has off every Wednesday. It has the following important machines.

14.4.1 CNC Laser Cutting Machine

The CNC Laser Cutting Machine work according to the program fed to the machine with two numbers of workers working on it. The setup time, downtime and operation time are determined by the stopwatch method for a week. The average actual speed for cutting one meter of sheet is 0.41 min; but average theoretical cutting speed is 0.30 min for one-meter cutting. There is no defect found during the observation period.

14.4.2 CNC Panel Bender Machine

The CNC Panel Bender Machine is operated by a worker who is responsible for all the operations and maintenance of it. The program is fed by the operator according to the material available for doing the operation. The operations involve loading of sheet, feeding program, unloading the parts and hemming of parts. The cycle time of each part shown on the dedicated computer screen is noted as well as the actual cycle time of each part is calculated by the stopwatch method. No such defects were found during the observation period.

14.5 OEE Computation

To improve anything, we need to know the current status of it. After the data collection, the calculation of availability, performance and quality rate is done. This will help to know where the actual problem is in the CNC machines for further improvements.

14.5.1 CNC Laser Cutting Machine

The Laser Cutting Machine is available for eight and a half hours, i.e., 510 min including a lunch break of thirty minutes. For each day, the time required for maintenance of the machine is almost thirty minutes which includes cleaning of the machine, nozzle checking, cylinder checking, tool checking, etc. The planned downtime includes setup time for the machine, lunch break, maintenance time and off time of the machine. The unplanned downtime is the unproductive time which includes short stoppages like waiting for an order list, taking sheets out on the table, cylinder change time, etc. Table 14.1 illustrates the calculation of the OEE without improvement in the current operating process. Equation (14.1) is used to calculate the OEE of the machine whereas Eqs. (14.4), (14.5) and (14.6) are used to calculate the availability, performance and quality rate. The Performance rate is determined with the theoretical time to the actual time for cutting a one-meter sheet.

$$\text{Planned Time} = \text{Total Available Time} - \text{Planned Downtime} \tag{14.2}$$

$$\text{Operating Time} = \text{Planned Time} - \text{Unplanned Downtime} \tag{14.3}$$

$$\text{Availability} = \frac{\text{Operating Time}}{\text{Planned Time}} \times 100 \tag{14.4}$$

$$\text{Performance} = \frac{\text{Theorotical Time}}{\text{Actual Time}} \times 100 \tag{14.5}$$

$$\text{Quality} = \frac{\text{Total Quantity} - \text{Total Defect}}{\text{Total Quantity}} \times 100 \tag{14.6}$$

14.5.2 CNC Panel Bender Machine

The OEE calculation of CNC Panel Bender is almost the same as that of the CNC Laser Cutting Machine, only the performance rate is calculated with the help of the theoretical cycle time and actual cycle time of each part whereas the planned downtime includes hemming operation also. Equation (14.4) is used to calculate the availability rate in which the operating time that includes unplanned downtime is mainly due to the waiting of parts for processing, operator busy in other work, parts handling, parts checking, etc. (Table 14.2).

Table 14.1 CNC laser cutting machine OEE without improvements

CNC laser cutting before OEE improvement		6–Nov–18	12–Nov–18	16–Nov–18	17–Nov–18	18–Nov–18	19–Nov– 18	3–Dec– 18	Overall values
A	Total available time	510	510	510	510	510	510	510	3570
B	Planned time	284	249	365	345	392	60	300	1995
C	Operating time	224	189	305	255	302	40	195	1510
D	Availability	78.87	75.90	83.56	73.91	77.04	66.67	65.00	75.69
E	Theoretical time for cutting 1 m sheet	0.32	0.42	0.33	0.22	0.29	0.34	1.23	0.45
F	Actual time for cutting 1 m sheet	0.48	0.49	0.43	0.24	0.39	0.48	1.75	0.61
G	Performance	66.67	85.71	76.74	91.67	74.36	70.83	70.29	73.94
H	Total defect	0	0	0	0	0	0	0	0
I	Total quantity	1	14	6	8	23	1	14	67
J	Quality	100	100	100	100	100	100	100	100
K	OEE %	52.58	65.06	64.13	67.75	57.29	47.22	45.69	55.97

Table 14.2 CNC panel bender OEE without improvements

CNC panel bender before OEE		7–Dec–18	8–Dec–18	9–Dec–18	10–Dec–18	14–Dec–18	24–Dec–18	Overall Values
A	Total available time	510	510	510	510	510	510	3060
B	Planned time	410	348	382	304	373	410	2227
C	Operating time	125	193	152	124	58	170	822
D	Availability	30.49	55.46	39.79	40.79	15.55	41.46	36.91
E	Theoretical time	29.13	49	23.5	24.15	9.73	29.52	165.03
F	Actual time	31.65	52.65	25.33	26.15	10.48	32.03	178.29
G	Performance	92.04	93.07	92.78	92.35	92.84	92.16	92.56
H	Total defect	0	0	0	0	0	0	0
I	Total quantity	6	4	4	2	1	5	22
J	Quality	100	100	100	100	100	100	100
K	OEE %	28.06	51.61	36.92	37.67	14.44	38.21	34.17

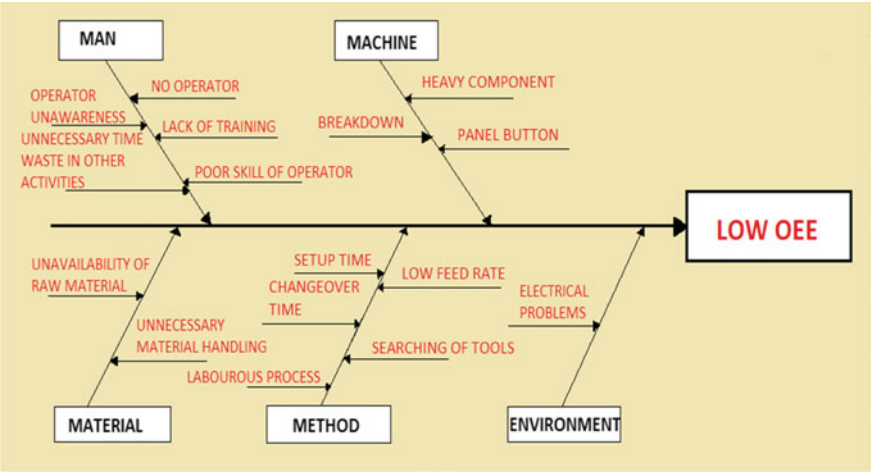

Fig. 14.1 Root cause analysis of CNC laser cutting machine and CNC panel bender machine

14.6 Improvement Techniques

The tools and techniques used for the improvements are discussed below with respect to the CNC machines.

14.6.1 Root Cause Analysis

Root cause analysis is a problem solving techniques that helps to recognize the root cause of faults or problems. There are problems in all aspects of OEE that was calculated for the CNC machines. Hence, the cause and effect diagram helps to find the causes of the low OEE. This analysis is done with the help of brainstorming method and the previous record of the breakdown of the CNC machines as shown in Fig. 14.1.

14.6.2 Six Big Losses

The Primary causes shown in Fig. 14.1 are used to find out the six big losses to find out the critical causes of the CNC machines. Table 14.3 shows the six big losses with respect to the CNC Laser Cutting machine and CNC Panel Bender machine.

This analysis will further help in distinguishing the Value added, Non-value added and Non-value added but necessary activities for improvements in the process and in the machines.

Table 14.3 Six big losses with respect to CNC machines

Factors	Loss category	Six big losses category	Event problems with respect to CNC machines
Availability	Downtime loss	Breakdown	• Electrical problems
		Setup and adjustment	• No operator • Lack of training • Operator unawareness • Poor skill of operator • Busy operator • Searching of tools
Performance	Speed loss	Small Stops	• Unavailability of raw material • Unnecessary material handling • Heavy component • Machine worn-out
		Reduced speed	• Low feed rate • Dimension check
Quality	Quality loss	Start-up reject	Nil
		Production reject	Nil

14.6.3 Kobetsu Kaizen

"Kaizen"—a Japanese term—means continuous improvement, taken from words "Kai, which means continuous and "zen" which means improvement [4]. It is a lean tool that is used for minimizing waste. The Kaizen Event was conducted with the help of a Kaizen team that includes white-collar employees to blue-collar employees. With the assistance of this Kaizen team, the process of improvement and suggestions were led for four days. The Kaizen report which shows the scenario of before improvement and after improvement are illustrated in Figs. 14.2, 14.3 and 14.4. Figure 14.2 shows

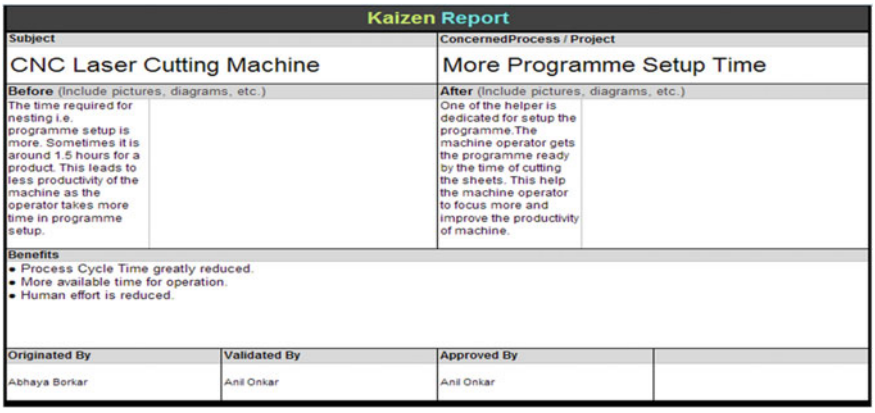

Fig. 14.2 The Kaizen event report of CNC laser cutting machine

Sheet 1 of 2

Kaizen Report

Subject	Concerned Problem
CNC Panel Bender Machine	Travelling Time

Before (Include pictures, diagrams, etc.)

The operator takes more time to reach to the work platform. Also, operator needs to crosscheck the programme, for that the programming pannel was not in proper position.

After (Include pictures, diagrams, etc.)

The position of programming panel is changed due to which operator takes less time than before to reach to the work platform. This setup will helps in reducing the loading and unloading time of the material.

Benefits

- Ease of operation.
- Human effort is reduced.

Originated By	Validated By	Approved By	
Abhaya Borkar	Anil Onkar	Anil Onkar	

Fig. 14.3 The Kaizen event report 1 of CNC panel bender machine

Sheet 2 of 2

Kaizen Report

Subject	Concerned Problem
CNC Panel Bender Machine	Oil filling

Before (Include pictures, diagrams, etc.)

The oil tank is located at the back side of the machine. The oil level is not visible from the front side hence the operator needs to go at the back and check the oil level daily before the start of the machine.

After (Include pictures, diagrams, etc.)

I recommend to install the liquid level indicator with alarm system as it is cheap. This will helps the machine from wear out. Also, operator need not to check it daily.

Benefits

- Helps the machine from wear out.
- Human effort will considerably reduce.

Originated By	Validated By	Approved By	
Abhaya Borkar	Anil Onkar	Anil Onkar	

Fig. 14.4 The Kaizen event report 2 of CNC panel bender machine

the Kaizen report of CNC Laser Cutting Machine whereas Figs. 14.3 and 14.4 show the Kaizen report of CNC Panel Bender Machine.

In CNC Laser Cutting Machine, from the observation and data, the main reason of losses are found to be the setup time and small stoppages whereas, in CNC Panel Bender, there was no such problem with the setup time but the other unplanned time like short stoppages, waiting for material, material handling, etc. was more. For

doing hemming of parts, the operator requires more time. To overcome this, a lean tool SMED was implemented with the help of the Kaizen team.

14.6.4 SMED-Single Minute Exchange of Die

SMED is an element of Kaizen and Total Productive Maintenance created by Shigeo Shingo in the 1950s. SMED lessens the setup time by eliminating wastes and unwanted processes and furthermore improves the current setup process and manufacturing flexibility [5]. The following methodology was used to implement SMED as shown in Fig. 14.5. Firstly, the methodology was adopted on the CNC Laser Cutting Machine and then the CNC Panel Bender Machine that results in distinguishing the operation between internal setup and external setup. The internal setups are those which are carried out when the machine has stopped whereas the external setups are those which are carried out when the machine is running. The internal setup activities found in both CNC machines are program setup, loading, and unloading.

In CNC Laser Cutting Machine, the program setup operation was carried out by the same operator responsible for doing the other operations of the machine due to which the planned time and operating time reduces. This internal setup activity is converted to external setup activity by appointing a new skilled operator and a new computer along with software for setting the program in laser machine are used because of which the time required by the machine operator for program setup gets reduced. This helps in increasing the operating and planned time to do more work. Thus, increases the availability rate of CNC Laser Cutting.

In CNC Panel Bender, the main losses found are small stoppages like busy operator, loading and unloading time, blade change time, hemming time for which operator had to go to the power press machine, etc. All these losses are taken into consideration to improve the productivity of the machine. Now, two operators are working on CNC Press Break, each operator gets a specific operation to do. Due to which, the time required for processing the parts is minimized with reduced losses. By doing this, the hemming operation which was internal setup activity is now converted to

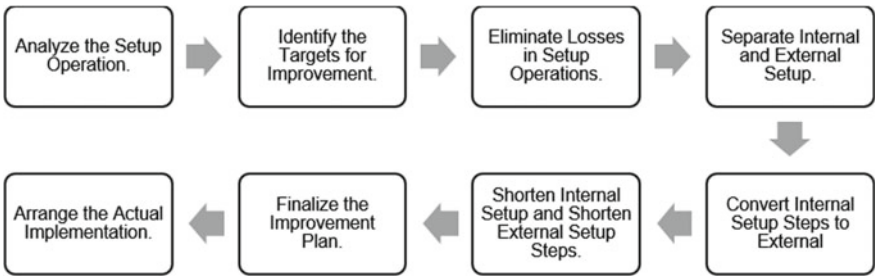

Fig. 14.5 Methodology to implement SMED

Table 14.4 Comparison of machine idle time of sample data

Algorithm used	CNC laser cutting machine in minutes	CNC panel bender in minutes
FCFS	390	510
SPT	380	500
General SB routine	360	480
Local search	230	350

the external setup activity. When the hemming operation is carried out by the other operator on a power press machine, the main operator performs the operation on the other available parts.

14.6.5 Scheduling of CNC Laser Cutting and CNC Panel Bender

For Scheduling, software "LEKIN" is used which is an interactive scheduling system for a machine environment which is a freely available source. This software compares different machine shop scheduling algorithms like Shortest Processing Time (SPT), Longest Processing Time (LPT), First Come First Serve (FCFS), General SB Routine, etc. [6]. In present, the orders are processed in First Come First Serve manner. Using optimized (least make-span time) scheduling, i.e., reducing machine idle time, the further OEE improvement can be done. The author recommended scheduling the data by using LEKIN software. A sample data was taken to analyze the difference in machine idle times for different scheduling algorithms shown in Table 14.4.

The Gantt chart is generated by LEKIN software which shows worst condition as using FCFS rule and best condition as using Local Search Algorithm shown in Figs. 14.6 and 14.7 respectively.

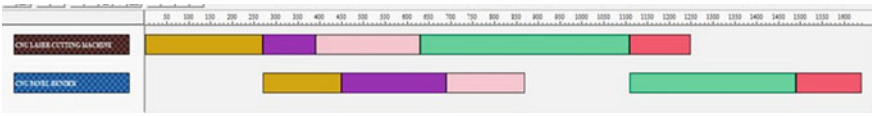

Fig. 14.6 Scheduling using FCFS rule

Fig. 14.7 Scheduling using local search algorithm

14.7 Results and Conclusion

After the implementation of the lean tools and techniques, the calculation of OEE of CNC Laser Cutting and CNC Panel Bender with improvements are done and is illustrated in Tables 14.5 and 14.6 respectively which shows that the availability rate of both the machines has increased that leads to increase in OEE of both the machines.

The recommended value of OEE for a continuous production process is 85%. The main reason for the difference between the recommended value and the actual value of both the machines is the availability factor. With improvements, the availability rate of CNC Laser Cutting Machine has increased from 75.69 to 80.01% whereas the availability rate of CNC Panel Bender has increased from 36.91 to 59.07%. The overall OEE of the CNC Laser Cutting and CNC Panel Bender are increased by 2.65 and 18.85% shown in Table 14.7.

The above results show that although the OEE values of the machines are not as per recommended value but it has been improved from the actual value. The recommended value of OEE is difficult to achieve as it requires continuous production run. Kaizen is a never-ending process. More Kaizen event should be conducted for further improvements.

Table 14.5 CNC laser cutting machine OEE after improvement

CNC laser cutting after OEE		1–Mar–19	3–Mar–19	4–Mar–19	10–Mar–19	11–Mar–19	14–Mar–19	16–Mar–19	Overall
A	Total available time	510	510	510	510	510	510	510	3570
B	Planned time	320	403	50	108	196	292	282	1651
C	Operating time	275	343	30	78	136	237	222	1321
D	Availability	85.94	85.11	60.00	72.22	69.39	81.16	78.72	80.01
E	Theoretical time for cutting 1 m sheet	0.28	0.3	0.32	0.31	0.3	0.31	0.29	0.30
F	Actual time for cutting 1 m sheet	0.4	0.39	0.4	0.43	0.43	0.43	0.4	0.41
G	Performance	70.00	76.92	80.00	72.09	69.77	72.09	72.50	73.26
G	Total defect	0	0	0	0	0	0	0	0
I	Total quantity	6	6	1	1	1	1	1	17
J	Quality	100	100	100	100	100	100	100	100
K	OEE %	60.16	65.47	48.00	52.07	48.41	58.51	57.07	58.62

Table 14.6 CNC panel bender machine OEE with improvement

CNC panel bender after OEE		2–Mar–19	5–Mar–19	7–Mar–19	12–Mar–19	15–Mar–19	22–Mar–19	Overall
A	Total available time	510	510	510	510	510	510	3060
B	Planned time	127	90	115	120	68	103	623
C	Operating time	87	50	55	85	33	58	368
D	Availability	68.50	55.56	47.83	70.83	48.53	56.31	59.07
E	Theoretical time	38.33	28.8	39.05	38.87	14.5	20.88	180.43
F	Actual time	41.62	30.83	48.95	41.85	15.52	22.23	201
G	Performance	92.10	93.42	79.78	92.88	93.43	93.93	89.77
H	Total defect	0	0	0	0	0	0	0
I	Total quantity	4	3	10	4	1	3	25
J	Quality	100	100	100	100	100	100	100
K	OEE %	63.09	51.90	38.15	65.79	45.34	52.89	53.02

Table 14.7 Comparison between recommended value and actual value before and after implementation [7]

OEE factors	Recommended value (%)	Actual value before improvement		Actual value after improvement	
		CNC laser cutting (%)	CNC panel bender (%)	CNC laser cutting (%)	CNC panel bender (%)
Availability	90	75.69	36.91	80.01	59.07
Performance	95	73.94	92.56	73.26	89.77
Quality	99.90	100.00	100.00	100	100
OEE	85	55.97	34.17	58.62	53.02

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