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A Case Study to Determine OEE – A KPI Representing the Overall Productivity of a Machine

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Abstract

The industrial sector has experienced an exceptional degree of change in the past few decades. Also, remarkable developments have taken place in the maintenance management systems to reduce downtime and various losses associated with it. Nowadays maintenance is never treated as a profitless activity, instead it is considered as an integral part of business which improves quality of the products as well as productivity of the machines. Ensuring world-class standard of operations to meet the customer requirements is a major challenge to any manufacturing industry. The industry must be in a position to provide the best in class quality of goods and services to its customers. This research work is carried out in a small and medium scale manufacturing industry located in the southern part of Karnataka state. Initially two mechanical presses – one having 600 tonne and the other with 800 tonne capacity were selected. The previous performances of the presses were studied from their breakdown details collected from the industry. Breakdown details for the specific period were collected and analyzed to calculate monthly Overall Equipment Effectiveness (OEE) for both the mechanical presses. OEE is a Key Performance Indicator (KPI) representing the overall productivity of any machine. These monthly OEE values were then averaged and the average OEE was compared to the world-class OEE. From the study carried out, it was observed that average OEE of the 600 tonne press was very low when compared to the world-class OEE target range (60-85%). Total Productive Maintenance (TPM) is found to be an effective maintenance strategy to improve the OEE of the equipment. Hence in order to improve the OEE, it was decided to implement TPM on 600 tonne mechanical press.

Keywords: *OEE, KPI, TPM, world-class OEE, mechanical press, downtime, productivity*

1.0 Introduction

Small and Medium Enterprises (SMEs) have undergone a remarkable change in the past few years in terms of technology used, degree of automation, maintenance systems, etc. These SMEs are developing their maintenance systems in order to make the best possible use of energy and available resources. Integrated with the business of an organization, maintenance activities impart value addition to the machinery and equipment. Maintenance improves the quality of the products, increases the productivity of the machines and confirms the availability of the production equipment in the long run. Hence it is very important for any SME to adopt a proper maintenance system for its overall development. Total Productive Maintenance (TPM) is one of the Japanese modern maintenance management systems whose target is to reduce downtime, waste, defects and hazards to zero[1]. TPM combines production and maintenance

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activities, increases the effectiveness of plant and machinery, ensures total involvement of management and employees and initiates self-governed maintenance activities by the machine operators[2,3]. TPM pillars include 5S, autonomous, planned and quality maintenance, continuous improvement, training, TPM for office and safety, health and environment[4]. TPM applications can be realized in variety of organizations such as production plants, hospitals, construction industry, etc.[5].

Overall Equipment Effectiveness (OEE) is a Key Performance Indicator or performance driver in TPM which offers a way to measure the effectiveness of single equipment to a complete manufacturing unit[6,7,8]. It is an index commonly used in the manufacturing industries to assess performance and productivity of a machine or a process[1,9]. The percentage OEE will help to identify the rise or fall of equipment performance over a period of time. It ensures the identification and elimination of major reasons for failure and poor performance of a machine and accordingly helps in prioritizing the improvement activities[10]. OEE includes six metrics – OEE, total effective equipment performance, loading, availability, performance and quality[6]. OEE brings together the operation, maintenance and management of production equipment and resources.

2.0 OEE Calculation

The OEE can be found out for any manufacturing equipment or process[11]. OEE identifies availability, performance and quality for any equipment and it can be calculated as the product of these three factors, where:

$$\text{Availability} = \frac{\text{Net operating time}}{\text{Net available time}} \times 100 \quad \text{... (1)}$$

$$\text{Performance} = \frac{\text{Ideal cycle time} \times \text{processing quality}}{\text{Net operating time}} \quad \text{... (2)}$$

$$\text{Quality} = \frac{\text{Total processed quantity} - \text{defective quantity}}{\text{Total processed quantity}} \quad \text{... (3)}$$

$$\text{OEE} = \text{Availability} \times \text{Performance} \times \text{Quality} \quad \text{... (4)}$$

OEE is affected by six major losses[12,13] which include:

- Breakdown losses and set-up/adjustment losses which are going to affect the availability of the machine.
- Idling/minor stop losses and reduced speeds which are going to affect the performance of the machine.
- Start-up losses and quality defects/reworks are due to the defects in the manufactured products and hence they are going to affect the quality.

Thus it is necessary to find out these losses while computing OEE-which is the function of availability, performance and quality. OEE is commonly used as a powerful tool to measure the present condition of the machine and to initiate the improvement programme through TPM[7]. Usually the effectiveness of TPM implementation is measured in terms of OEE of the machine[14]. TPM improves OEE of the machine by enhancing availability, performance and quality[10]. Normally standard values of availability, performance and quality are considered to be 90%, 95% and 99% respectively and 85% is considered as a benchmarking value for world-class OEE[15].

3.0 Details of the Critical Machines

This research work is carried out in a manufacturing unit located in Karnataka, India. The manufacturing unit is categorized under SME. This unit produces pulley, pinion, relay case, sleeve, running pulley, magnet core, rotor, spark plug housing, etc. It provides major facilities such as cold forging, CNC milling, heat treatment, etc. The cold forging consists of hydraulic and mechanical presses. The capacity of the machines ranges from 300 tonnes to 1500 tonnes. The critical machines selected for this research work are 600 tonne and 800 tonne mechanical presses (Make-Komatsu Maypres). A mechanical press punches, forms or assembles metal by means of a die attached to the ram or slide. The workpiece is kept on a bottom die and it is struck with a top die, thus metalworking takes place. A typical mechanical press is shown in Figure 1 and its principle of working is shown in Figure 2.

Figure 1: A Mechanical Press

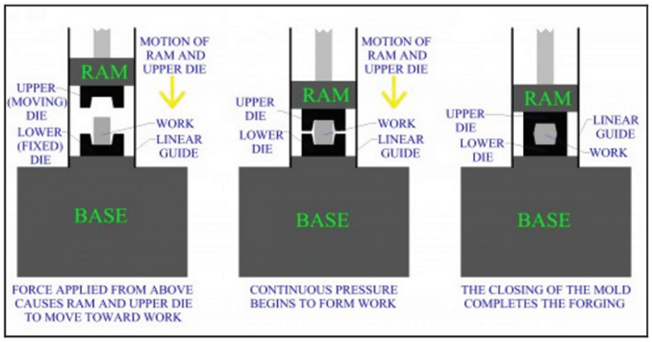

Figure 2: Working Principle of a Mechanical Press

4.0 Methodology

This research work is carried out in a SME of manufacturing domain located in Karnataka state, India. The downtime data for 600 tonne and 800 tonne mechanical presses are collected from the selected manufacturing industry. These presses had several breakdowns in a year and its downtime was hampering the regular production. The data has been collected for 10 consecutive months in case of 600 tonne press and 9 consecutive months in case of 800 tonne press. The monthly data collected for the 600 tonne and 800 tonne mechanical presses are analysed to calculate their availability, performance and quality. The overall equipment effectiveness (OEE) is a function of these three parameters. The monthly availability, performance and quality percentages are multiplied to obtain monthly OEE percentage values. These monthly values are then averaged to obtain the OEE values for 600 tonne and 800 tonne mechanical presses. These values are then compared to the world-class OEE value. Suitable measures are suggested to improve the existing OEE value if it is less than the world-class OEE.

5.0 Results and Discussion

10 consecutive months' breakdown details of 600 tonne mechanical press and 9 consecutive months' breakdown details of 800 tonne mechanical press are analysed to calculate the availability percentage. The total downtime in each month is calculated which includes both planned and unplanned downtimes. The planned downtime includes planned stoppages, initial cleaning hours, preventive maintenance inspection and number of Sundays during which the press is not available for operation. The machine will remain unavailable for production only for 4 hours on every Sunday. The unplanned downtime includes power failures, machine downtimes, unplanned stoppages and raw material waiting times. The monthly working time for each press is obtained by subtracting all downtimes (in hours) from the total available hours in the respective month. Net

Table 1: Downtime data for 600 tonne mechanical press

Month of a particular year (2020-21)	No.of days	Planned downtime						Unplanned downtime					
		Planned stoppage (Hours)	Initial cleaning (Hours)	PMI (Hours)	No. of Sundays	No. of holidays	Available time Hours)	Power b/d (Hours)	Downtime (Hours)	Unplanned stoppages (Hours)	Setting (Hours)	Raw material (Hours)	Working time (Hours)
Jun	30	45	30	0	4	0	629	2.06	0	11	18.5	0	597.44
Jul	31	46.5	31	0	5	0	646.5	1.13	72	21	26	12.16	514.21
Aug	31	46.5	31	0	4	2	602.5	1.8	0	1.75	22	3.25	573.7
Sep	30	45	30	0	4	2	581	1.6	245	17.25	10.58	0	306.57
Oct	31	46.5	31	0	5	2	598.5	1.13	398	3	7.16	0	189.21
Nov	30	45	30	0	4	1	605	0.93	394	6.5	1	0	202.57
Dec	31	46.5	31	0	4	0	650.5	0.73	6.5	46.5	20.91	1.5	574.36
Jan	31	46.5	31	0	4	2	602.5	1.13	0	25.91	21.75	0	553.71
Feb	28	42	28	0	4	0	586	1	0	49	25	4	507
Mar	31	46.5	31	0	4	0	650.5	0.67	0	34.5	29.42	42.16	543.75

Table 2: Downtime data for 800 tonne mechanical press

Month of a particular year (2020-21)	No.of days	Planned downtime					Available time Hours)	Unplanned downtime					Working time (Hours)
		Planned stoppage (Hours)	Initial cleaning (Hours)	PMI (Hours)	No. of Sundays	No. of holidays		Power b/d (Hours)	Downtime (Hours)	Unplanned stoppages (Hours)	Setting (Hours)	Raw material (Hours)	
Jul	31	46.5	31	1.5	5	0	645	1.13	64	7.58	26.25	19.91	526.13
Aug	31	46.5	31	0	4	2	602.5	1.8	97	5.5	20.5	11.33	466.37
Sep	30	45	30	0	4	2	581	1.6	0	16.5	20.83	1	541.07
Oct	31	46.5	31	0	5	2	598.5	1.13	6	11.25	22.5	0	557.62
Nov	30	45	30	0	4	1	605	0.93	5	17	25.41	1.5	555.16
Dec	31	46.5	31	0	4	0	650.5	0.73	0	45.32	23.33	0	581.12
Jan	31	46.5	31	0	4	2	602.5	1.13	25	42.25	20	0	514.12
Feb	28	42	28	183.3	4	0	402.7	1	139.7	34.33	11	0	216.68
Mar	31	46.5	31	0	4	0	650.5	0.66	29.83	43	28.83	0	548.18

available time for each month is found. Availability is the ratio of net working time and net available time. The downtime data collected, segregated and tabulated for 600 tonne and 800 tonne mechanical press are shown in Tables 1 and 2 respectively. The availability, performance and quality percentages for 600 tonne mechanical press are shown in Tables 3, 4 and 5 respectively. Table 6 shows the OEE values (percentage) of 600 tonne mechanical press. Similarly the availability, performance and quality percentages for 800 tonne mechanical press are shown in Tables 7, 8 and 9 respectively. Table 10 shows the OEE values (percentage) of 800 tonne mechanical press. Table 11 shows average OEE percentage for 600 tonne and 800 tonne presses.

The average OEE percentage of 600 tonne mechanical press was found to be very low when compared to that of 800 tonne mechanical press. This is because 600 tonne press was suffered from major breakdowns in few months of the year resulting in lower values of availability and performance when compared to 800 tonne press. Figures 3 and 4 show the monthly values of availability, performance, quality and OEE percentages of 600 tonne and 800 tonne mechanical press respectively. Figure 5 shows OEE comparison for both the presses.

Figures 3 and 4 reveal that OEE values of both 600 tonne and 800 tonne press are greatly affected by the reduction in the availability and performance percentages. The quality percentage is found to be 100% in few months or very close to 100% in the remaining months. It is observed that availability and performance are the main contributors to the reduced OEE values of both the presses, when the quality is almost equal to 100%. Table 11 and Figure 5 show that the OEE of 800 tonne mechanical press is found to be higher than the OEE of 600 tonne mechanical press. The average OEE of 800 tonne mechanical press (65.14%) lies in the target range

Table 3: Availability percentage of 600 tonne mechanical press

Month	Days	Available time (Hours)	Working time (Hours)	Availability (%)
Jun	30	629	597.44	95.0
Jul	31	646.5	514.21	79.5
Aug	31	602.5	573.7	95.2
Sep	30	581	306.57	52.8
Oct	31	598.5	189.21	31.6
Nov	30	605	202.57	33.5
Dec	31	650.5	574.36	88.3
Jan	31	602.5	553.71	91.9
Feb	28	586	507	86.5
Mar	31	650.5	543.75	83.6

Table 4: Performance percentage of 600 tonne mechanical press

Month	Working time (Hours)	Designed cycle time(s) (mean)	Actual cycle time (s) (max)	Production in available time (units)	Quantity produced (units)	Performance (%)
Jun	597.44	4.23	4.27	5,08,460	3,32,354	65.4
Jul	514.21	4.23	4.27	4,37,626	2,98,032	68.1
Aug	573.7	4.23	4.27	4,88,255	3,40,944	69.8
Sep	306.57	4.23	4.27	2,60,911	1,48,859	57.1
Oct	189.21	4.23	4.27	1,61,030	1,50,140	93.2
Nov	202.57	4.23	4.27	1,72,400	1,46,652	85.1
Dec	574.36	4.23	4.27	4,88,817	2,96,067	60.6
Jan	553.71	4.23	4.27	4,71,243	3,05,930	64.9
Feb	507	4.23	4.27	4,31,489	2,66,248	61.7
Mar	543.75	4.23	4.27	4,62,769	3,14,483	68.0

Table 5: Quality percentage of 600 tonne mechanical press

Month	Quantity produced (units)	Defective pieces (units)	Quality (%)
Jun	3,32,354	175	99.9%
Jul	2,98,032	0	100%
Aug	3,40,944	0	100%
Sep	1,48,859	89	99.9%
Oct	1,50,140	0	100%
Nov	1,46,652	0	100%
Dec	2,96,067	66	100%
Jan	3,05,930	265	99.9%
Feb	2,66,248	144	99.9%
Mar	3,14,483	0	100%

of OEE yardstick values (60 to 85%). 60% OEE percentage is considered to be typical for discrete manufacturing. This OEE value highlights that industries have enough opportunity for improving their performance to reach world-class yardstick of 85% OEE. But the average OEE of 600 tonne mechanical press is found to be very low (49.40%) and is less than the lower value of target range of OEE yardstick values (60%).

Total effective equipment performance (TEEP) is a performance metric which takes into account both equipment losses and schedule losses. TEEP evaluates the percentage of all time that is actually productive. The term ‘all time’ refers to the calendar number of days or hours. Typically, 100% TEEP indicates the absence of equipment losses and schedule losses and it certifies only quality products are being

Table 6: OEE percentage of 600 tonne mechanical press

Month	Availability (%)	Performance (%)	Quality (%)	OEE (%)
Jun	95.0	65.4	99.9	62.05
Jul	79.5	68.1	100	54.17
Aug	95.2	69.8	100	66.49
Sep	52.8	57.1	99.9	30.09
Oct	31.6	93.2	100	29.48
Nov	33.5	85.1	100	28.48
Dec	88.3	60.6	100	53.47
Jan	91.9	64.9	99.9	59.61
Feb	86.5	61.7	99.9	53.36
Mar	83.6	68.0	100	56.81
Average	73.79	69.39	99.96	49.401

Table 7: Availability percentage of 800 tonne mechanical press

Month	Days	Available time (Hours)	Working time (Hours)	Availability (%)
Jul	31	645	526.13	81.57
Aug	31	602.5	466.37	77.40
Sep	30	581	541.07	93.12
Oct	31	598.5	557.62	93.16
Nov	30	605	555.16	91.76
Dec	31	650.5	581.12	89.33
Jan	31	602.5	514.12	85.33
Feb	28	402.67	216.68	53.81
Mar	31	650.5	548.18	84.27

Table 8: Performance percentage of 800 tonne mechanical press

Month	Working time (Hours)	Designed cycle time (s) (mean)	Actual cycle time (s) (max)	Production in available time (units)	Quantity produced (units)	Performance (%)
Jul	526.13	5.75	6.5	329403	260685	79.14
Aug	466.37	5.75	6.5	291988	234403	80.28
Sep	541.07	5.75	6.5	338757	268374	79.22
Oct	557.62	5.75	6.5	349119	278813	79.86
Nov	555.16	5.75	6.5	347578	285345	82.09
Dec	581.12	5.75	6.5	363831	297650	81.80
Jan	514.12	5.75	6.5	321884	229790	71.39
Feb	216.68	5.75	6.5	135661	102829	75.79
Mar	548.18	5.75	6.5	343208	250912	73.10

Table 9: Quality percentage of 800 tonne mechanical press

Month	Quantity produced (units)	Defective pieces (units)	Quality (%)
Jul	260685	0	100.00
Aug	234403	83	99.96
Sep	268374	122	99.95
Oct	278813	0	100.00
Nov	285345	0	100.00
Dec	297650	0	100.00
Jan	229790	0	100.00
Feb	102829	0	100.00
Mar	250912	666	99.73

Table 10: OEE percentage of 800 tonne mechanical press

Month	Availability (%)	Performance (%)	Quality (%)	OEE (%)
Jul	81.57	79.14	100.00	64.55
Aug	77.40	80.28	99.96	62.11
Sep	93.12	79.22	99.95	73.73
Oct	93.16	79.86	100.00	74.40
Nov	91.76	82.09	100.00	75.32
Dec	89.33	81.80	100.00	73.07
Jan	85.33	71.39	100.00	60.91
Feb	53.81	75.79	100.00	40.78
Mar	84.27	73.10	99.73	61.43
Average	83.31	78.07	99.96	65.14

produced. TEEP is the product of OEE and utilization, where utilization refers to the ratio of the available time for production to all time. Utilization is normally expressed in percentage and can be regarded as the portion of the time the equipment is used for the production. TEEP takes into account the full capacity of the production unit. Thus OEE is the ratio of fully productive time to planned productive time, whereas TEEP is the ratio of planned production time to all time[16].

The equipment utilization and TEEP values are calculated for the 600 tonne mechanical press using the downtime data as shown below:

$$\text{Equipment Utilization} = \frac{\text{Total time available for production}}{\text{All-time}} \quad \text{... (5)}$$

$$= 6152/7296 = 84.3\%$$

Table 11: OEE percentage (Average) for 600 tonne and 800 tonne mechanical press

Machine	Average OEE percentage
600 tonne mechanical press	49.40
800 tonne mechanical press	65.14

$$\text{TEEP} = \text{Average OEE} \times \text{Utilization} \quad \text{... (6)}$$

$$= 0.4940 \times 0.843 = 41.64\%$$

The corrective measures must be implemented in order to increase the availability and performance of 600 tonne mechanical press thereby increasing OEE and TEEP.

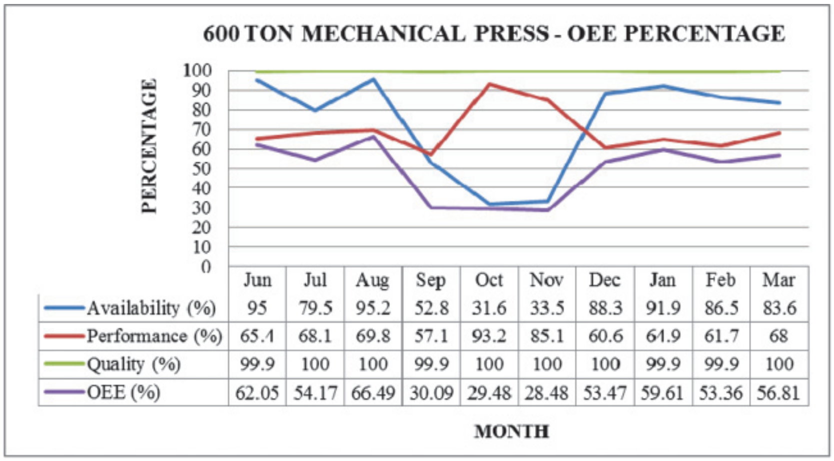

Figure 3: OEE percentage of 600 tonne mechanical press

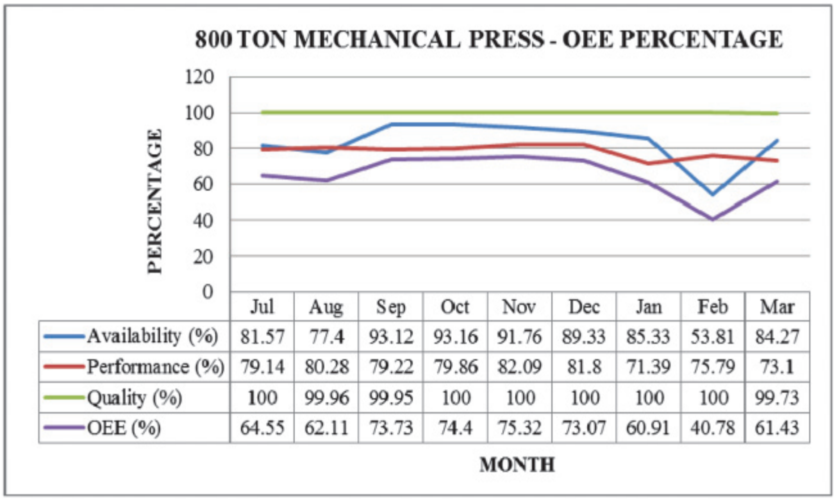

Figure 4: OEE percentage of 800 tonne mechanical press

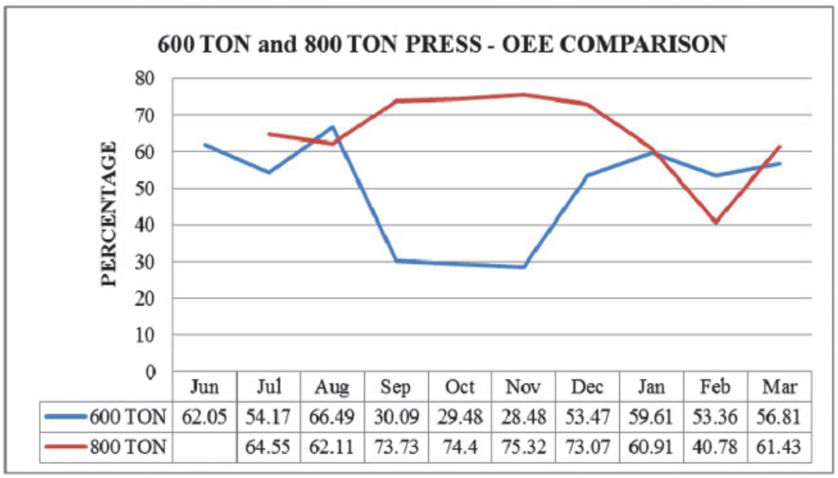

Figure 5: Comparison of OEE percentage for both the presses

6.0 Conclusion

OEE can be considered as a powerful benchmarking tool which can be used to measure the productivity improvement of the equipment. In this approach, collaborative efforts of the employees are directed towards improvements in the effectiveness of the machines by the elimination of various types of losses. This approach also provides the machine operators and supervisors an option to continuously monitor and take actions to prevent the problems which could result in breakdowns and quality losses. OEE computations help to identify the effective production time of a machine and the possible reasons for the productivity losses. It also helps the industries to set productivity improvements programmes using TPM framework by comparing current OEE with the world-class value.

This case study of determining the OEE was carried out in a manufacturing industry producing engineering and automotive components. After carrying out a detailed study on various machines available in the industry, two mechanical presses, one having 600 tonne capacity and the other with 800 tonne capacity were selected for further research. The past downtime details were collected for these two presses and their availability, performance and quality percentages were found. The average availability, performance and quality percentages for 600 tonne press were found to be 73.79, 69.39 and 99.96 respectively. The average availability, performance and quality percentages for 800 tonne press were found to be 83.31, 78.07 and 99.96 respectively. The average OEE of 600 tonne and 800 tonne presses was found to be 49.40% and 65.14% respectively. The average OEE of the 600 tonne mechanical press was very low when compared to the 800 tonne press. There is very large difference between the OEE value obtained and the world-class OEE value. It was found that the quality percentage of the 600 tonne press was very close to 100% and the availability and performance percentages were mainly contributing to the low OEE. The average OEE and the equipment utilization were multiplied to get the total effective equipment performance which was found to be 41.64%. Most of the literatures reveal that TPM is a performance improvement maintenance programme whose target is to achieve world-class OEE values by improving availability and performance of the machine. This study suggests that TPM implementation is one of the possible solutions to improve the OEE values and it is recommended to implement TPM on this mechanical press. The industry management has decided to implement TPM on 600 tonne mechanical press in order to improve its performance and availability which in turn will improve OEE and TEEP.

7.0 References

1. Nakajima, (1988): Introduction to Total Productive Maintenance. Productivity Press, Cambridge.
2. Nazim Baluch, et al., (2012): Measuring OEE in Malaysian Palm Oil Mills. *Interdisciplinary Journal of Contemporary Research in Business*, Vol. 4, No. 2, pp. 733-743.
3. Bhadury B., (2000): Management of productivity through TPM. Productivity, Vol. 41, No. 2, pp. 240-251.
4. Chetan S. Sethia, et al., 2014, Total Productive Maintenance- A systematic review. *International Journal for Scientific Research & Development*, Vol. 2, No.8, pp. 124-127.
5. Amit Kumar Gupta and R. K. Garg, (2012): OEE Improvement by TPM Implementation: A Case Study. *International Journal of IT, Engineering and Applied Sciences Research*, Vol. 1, No. 1, pp. 115-124.
6. R. Raghuram, (2014): Implementation of Overall Equipment Effectiveness (OEE). *Middle-East Journal of Scientific Research*, Vol. 20, No. 5, pp. 567-576.
7. A. Bangar, et al., (2013): Improving Overall Equipment Effectiveness by implementing Total Productive Maintenance in auto industry. *International Journal of Emerging Technology and Advanced Engineering*, Vol.3, No.6, pp. 590-594.
8. Aditya Parida and Udaya Kumar, (2009): Maintenance Productivity and Performance Measurement. Springer-Handbook of Maintenance Management and Engineering, ISBN: 978-1-84882-471-3, pp. 17-41.
9. Jitendra Kumar, (2022): Evidence of manufacturing productivity using TPM in Indian industry: A survey. *International Journal of Latest Engineering Science*, Vol. 5, No. 2, pp. 8-19.
10. S.D. Kalpande, (2014): OEE-An effective tool for TPM implementation- A case study. Proceedings of 8th International Quality Conference, Center for Quality, Faculty of Engineering, University of Kragujevac, pp. 521-526.
11. R.Vijayakumar and S.Gajendran, (2014): Improvement of Overall Equipment Effectiveness (OEE) in injection moulding process industry. *IOSR Journal of Mechanical and Civil Engineering,* pp. 47-60.
12. Mohamad Nasir et al., (2019): Application TPM to increase the effectiveness of engines with OEE as a tool to measure in the industrial packaging cans. *International Journal of Innovative Science and Research Technology,* Vol. 4, No. 7, pp. 1314-1331.
13. Muhammad Babar Ramzan et al., (2022): Development and evaluation of overall equipment effectiveness of knitting machines using statistical tools. SAGE Open, Vol.12, No.2, https://doi.org/ 10.1177/ 21582440221091249.
14. Vinayak Suryawanshi and Rajesh Buktar, (2015): Leveraging TPM for increase in the OEE of CNC machine. *International Journal of Modern Engineering Research*, Vol. 5, No. 9, pp. 18-26.
15. Blanchard B.S, (1997): An enhanced approach for implementing total productive maintenance in the manufacturing environment. *Journal of Quality in Maintenance Engineering*, Vol. 3, No.2, pp. 69-80.
16. Aswin Joseph and M S Jayamohan, (2017): Evaluation of Overall Equipment Effectiveness and Total Effective Equipment Performance: A Case Study. *International Journal of Advance Engineering and Research Development*, Volume 4, Issue 5, pp.343-346.