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Overall Equipment Effectiveness Analyse for Performance of CNC Milling Machine Operation

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Abstract. Overall equipment efficiency (OEE) is a large part of the maintenance system used by Japanese companies; Total Productive Maintenance (TPM). The value of OEE is affected by the often problematic production activities in machinery/production equipment such as damage to machine components resulting in reduced production, lowering engine production speed, preparation length and adjustment time, resulting in defective products and operating machines but not producing products. This paper will focus on the overall equipment efficiency of CNC Milling machine. The indicators of data parameter are used planned downtime, ideal cycle times, real-time cycles and daily operator reports (daily schedule controls) and direct data retrieval in the field. Where OEE calculation depends on availability, performance of efficiency, and rate of quality. The result has shown that the value of availability is 87%, performance of efficiency is 93% and OEE is 74%.

1. Introduction

The automotive and steel industries use several heavy equipment and control component in facilitating the transportation of components [1-2]. Roller, tube, excavator, etc. include heavy equipment that were often used in handling of component on production line, where heavy equipment and components which produced by machining and casting process [3-6]. For controlling the quality and movement component, it can be done by using PLC, microcontroller and other control system [7-8]. Machining process was requires machine tools such as lathe, milling machine, shape machine, CNC milling machine, drilling machine and other auxiliary equipment [3]. All types of machines and equipment require regular maintenance and repair. The routine of maintenance schedule or repairing process is sometimes could not come and touching the cause of machine utility. This might be affected to the quality and quantity of products. For this reason, the proper use of maintenance in the case of machine tools and auxiliary equipment should applied to meet the quality and quantity of products based on standard [9]. Use of routine maintenance in periodic maintenance scheduling and checking the state of each component in the machine tools (prevention and prediction) so that the improvements can be made to the efficiency of machine tools.

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The proposed improvements to machine tools are expected to be implemented effectively and efficiently. Effective and efficient improvements can be made by measuring machine performance and production equipment in the form of overall equipment effectiveness (OEE) [10]. Overall equipment efficiency (OEE) is a large part of the maintenance system used by Japanese companies, total maintenance productive (TPM) [11]. The value of OEE is affected by the often problematic production activities in machinery/production equipment such as damage to machine components resulting in reduced production, lowering engine production speed, preparation length and adjustment time, resulting in defective products and operating machines but not producing products.

This paper will focus on the effectiveness of the entire equipment of weight-bearing activities using the CNC Manufacturing process. The indicators are used the data on planned downtime, ideal cycle times, real-time cycles and daily operator reports (daily schedule controls) and direct data retrieval in the field. Where OEE calculation depends on availability, performance of efficiency, and rate of quality. The value of OEE for each company will meet the world-class standards if they meet the following criteria: 90% availability, 95% performance, 99.9%, quality, so that the average world class standard is 85% OEE.

2. Method

Experimental method is used in this research. Collected data by measurement time of operation process of CNC Milling machine. Analysis data has done by calculated the overall equipment effectiveness (OEE) depend on the time of processing process of product such as work time, delay time, breakdown time (maintenance time), downtime (set up time and adjustment time), availability value (loading time, down time, operation time), cycle time, normal time, standard time, performance efficiency, rate quality and overall equipment effectiveness (OEE).

Calculation of OEE depend on availability, performance efficiency and rate of quality. Calculation formula of OEE can be seen by Equation 1.

$$\text{OEE (\%)} = \text{Availability (\%)} \times \text{Performance efficiency (\%)} \times \text{Quality rate (\%)} \quad [1]$$

Where:

Availability is:

$$\text{Availability} = \frac{(\text{loading time} - \text{downtime})}{\text{loading time}} \times 100\% \quad [2]$$

Performance of efficiency is:

$$\text{Performance efficiency} = \frac{\textit{Processed amount x ideal cycle time}}{\textit{operation time}} \times 100\% \quad [3]$$

And rate of quality is:

$$\text{Rate of Quality} = \frac{(\textit{processed amount} - \textit{defect amount})}{\textit{processed amount}} \times 100\% \quad [4]$$

3. Results and Discussions

In data processing in the overall Equipment Efficiency Survey (OEE) research, data has been collected on CNC Manufacturing machines such as planned leisure data, ideal cycle times, actual cycle times and daily operator reports (daily schedule controls) and direct data retrieval in field.

3.1 Production data of door 3 Assy.

Data production of door 3 assy can be seen in Table 1. Table 1 shows that the total product, gross product and defect for 1 year. As shown in Table 1, the total of gross product is 1101 pieces and defect product is 90 pieces. Product defects depend on 71 pieces rework and 19 pieces scrap.

3.2 Work time and delay time of machine

Availability work time data depend on total work day/month and total work time per day (24 hours). Availability work time can be calculated by formula:

Availability time/month = Total Work D/M x Total Work Time (h) x Time (min)

Availability time/month = 21 day/month x 24 h x 60 min

Availability time/month = 30240 minute

Total annual data can be seen in the Table 2.

Total delay time for machine consist on the cleaning time, planned downtime, warm up time, general breakdowns, machine break and power cut-off. Total delay time machine in this research is 138548 minute as shown in Table 3 where the value of cleaning time are 3610 minute, 100035 minute for planned downtime, 3542 minute for warm up time, 8002 minute for general breakdown, 21988 minute for machine break and 1371 minute for power cut off. This value shows that the effect of planned downtime and machine break give more value for total delay time. Therefore the value of total delay time for machine is larger due to time for planned downtime and general breakdowns increased.

Table 1. Annual Data Production of Door 3 Assy

Month	Total Product (pieces)	Gross Product (pieces)	Defect (pieces)		
			Rework	Scrap	Total
March	106	98	6	2	8
Apr	102	95	6	1	7
Mei	95	86	7	2	9
June	100	94	4	2	6
July	81	73	6	2	8
August	97	90	6	1	7
Sept	104	95	7	2	9
Oct	99	92	5	2	7
Nov	88	76	10	2	12
Dec	106	100	5	1	6
Jan	110	105	4	1	5
Feb	103	97	5	1	6
Total	1191	1101	71	19	90

Tabel 2. Total Annual Data Availability Work Time

Month	Total Work Days/Month	Available time (minute)
March	21	30240
Apr	21	30240
Mei	20	28800
June	22	31680
July	16	23040
August	22	31680
Sept	21	30240
Oct	21	30240
Nov	22	31680
Dec	20	28800
Jan	21	30240
Feb	20	30240
Total	247	357120

3.3 Breakdown

Data of breakdown is get by measurement time before and after maintenance as seen at Table 4.

3.4 Availability

The downtime calculation for production processing get by using formula:

Downtime = Breakdown + Setup Time + Adjustment

Downtime = 605 minute + 600 minute + 292 minute = 1497 minute.

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Table 3. Annual Data Work Time and Delay Time of CNC Milling Machine

Month	Work time available (minute)	Delay of Machine						
		Cleaning time (minute)	Planned downtime (minute)	Warm up time (minute)	General breakdowns (minute)	Machine Break (minute)	Power cut-off (minute)	Total delay (minute)
March	30240	310	8505	292	605	2890	120	12722
Apr	30240	240	8505	288	651	2142	108	11934
Mei	28800	270	8100	275	744	1680	111	11180
June	31680	240	8910	312	715	1980	114	12271
July	23040	360	6480	312	560	1440	120	9272
August	31680	270	8910	332	733	1584	120	11949
Sept	30240	330	8505	275	639	1764	108	11621
Oct	30240	330	8505	280	717	1512	108	11452
Nov	31680	360	8910	292	823	2244	120	12749
Dec	28800	270	8100	292	605	1680	114	11061
Jan	30240	300	8505	300	602	1512	108	11327
Feb	28800	330	8100	292	608	1560	120	11010
Total	355680	3610	100035	3542	8002	21988	1371	138548

Table 4. Breakdown at CNC milling machine.

No	Type of Damage	Time for Report of Damage	Time of Maintenance		Breakdown time (s)
			Start	Finish	
1	Alarm 3 : Area Working Limit	20:15	20.20	21.20	3900
2	Alarm GPU Sack holder	8:42	8.47	9.00	1080
3	Alarm GPU Sack holder	15:37	15.41	15.55	1080
4	Alarm 3 : Area Working Limit	7:18	7.22	8.25	4020
5	Alarm Machine SV01 Y data Error	7:03	7.33	8.10	2400
6	Alarm GPU Sack holder	11:02	11.06	11.20	1080
7	Monitor Error	9:00	9.06	9.30	1800
8	Alarm GPU Sack holder	17:32	17.350	17.500	1080
Total of breakdown time					16440

Table 5 has shown that the total value of downtime is 15303 minute. The maximum value of downtime happen in November namely 1745 minute as shown in Table 5. This case due to the breakdown time in November is larger than other month. Breakdown time give a big effect in the maintenance and also needed long time for maintenance. Breakdown can be done by reparation or changing of component or part of machine so need time for finishing this activity. Set up time depend on the clean area, reading the engineering drawing of product, tools preparation, and set up equipment. After downtime calculation thus the loading time calculation by using formula:

Loading Time = Availability Time – Planned Downtime

Loading Time = 30240 minute – 8505 minute = 21735 minute

Total annual loading time calculation can be seen on Table 6.

Availability value on the March is:

$$\text{Availability} = \frac{(\text{loading time} - \text{downtime})}{\text{loading time}} \text{ x } 100\%$$

$$\text{Availability} = \frac{(21735 \text{ minute} - 1497 \text{ minute})}{21735 \text{ minute}} \text{ x } 100\% = 0.93$$

Availability value for annual year can be seen at Table 6.

Total annual downtime can be seen in the Table 5.

Table 5. Annual calculation of downtime

Month	Breakdown (minute)	Setup Time (minute)	Adjustment Time (minute)	Total Downtime (minute)
March	605	600	292	1497
Apr	651	606,6	288	939
Mei	744	637,5	275	1019
June	715	681	312	1708
July	560	600	312	1472
August	733	648	332	1713
Sept	639	637,5	275	914
Oct	717	606,6	280	997
Nov	823	630	292	1745
Dec	605	600	292	1497
Jan	602	621,4	300	902
Feb	608	654,9	292	900
Total				15303

Table 6. Calculation of loading time and Availability Value for Annual Year

No.	Month	Available Time (minute)	Planned Downtime (minute)	Loading Time (minute)	Downtime (minute)	Operation Time (minute)	Availability Rate
1	March	30240	8505	21735	1497	20238	0.93
2	Apr	30240	8505	21735	1546	20189	0.93
3	Mei	28800	8100	20700	1657	19044	0.92
4	June	31680	8910	22770	1708	21062	0.92
5	July	23040	6480	16560	1472	15088	0.91
6	August	31680	8910	22770	1713	21057	0.92
7	Sept	30240	8505	21735	1552	20184	0.93
8	Oct	30240	8505	21735	1604	20131	0.93
9	Nov	31680	8910	22770	1745	21025	0.92
10	Dec	28800	8100	20700	1497	19203	0.93
11	Jan	30240	8505	21735	1523	20212	0.93
12	Feb	28800	8100	20700	1555	19145	0.92
	Total	355680	100035	255645			
Average							0.93

3.5 Calculation of the performance of efficiency and rate quality

Calculation on performance of efficiency depend on the cycle time, operation time and processed amount. The value can be calculated by using formula:

Performance of efficiency = net operating rate x operating speed rate

$$\text{Performance efficiency} = \frac{\text{Processed amount x ideal cycle time}}{\text{operation time}} \text{ x } 100\%$$

Table 7. Normal and standard time of CNC Milling machine operation for annual year

Month	Work element	Cycle Time (minute)	Rating Factor	Normal Time (minute)	Allowance	Standard Time (minute/unit)
March	CNC Milling Machine Operation	123,09	0,15	141,55	22,00%	172,69
Apr		123,36	0,15	141,86	22,00%	173,07
May		123,91	0,15	142,50	22,00%	173,85
Jun		123,08	0,15	141,54	22,00%	172,68
Jul		122,70	0,15	141,11	22,00%	172,15
August		122,77	0,15	141,19	22,00%	172,25
Sept		123,42	0,15	141,93	22,00%	173,16
Oct		123,58	0,15	142,12	22,00%	173,38
Nov		124,44	0,15	143,11	22,00%	174,59
Dec		120,40	0,15	138,46	22,00%	168,92
Jan		123,04	0,15	141,50	22,00%	172,63
Feb		122,41	0,15	140,77	22,00%	171,74

Whereas:

$$\text{Operating speed rate} = \frac{\text{Ideal cycle time}}{\text{Actual cycle time}} \text{ x } 100\%$$

$$\text{Net Operating rate} = \frac{\text{Processed amount x actual cycle time}}{\text{operation time}} \text{ x } 100\%$$

Normal time can be calculated by:

$$\text{Normal Time} = \text{Observation time x } \frac{\text{Rating factor \%}}{100\%}$$

$$\text{Normal Time} = 123{,}09 \text{ minute x } (1+\frac{15}{100})$$

$$= 141{,}55 \text{ minute}$$

Table 7 shows that the value of normal and standard time of CNC Milling machine operation for annual years.

Standard time or ideal cycle time for March is:

$$\text{Standar time} = \text{Normal time x } \frac{100\%}{100\% - \text{Allowance \%}}$$

Standar time = 141, 55 minute x (1+0, 22)

Standar time = 172, 69 minute/unit

Calculation on actual cycle time for March is:

$$\text{Actual cycle time} = \frac{\text{Operation time}}{\text{Processed amount}}$$

$$\text{Actual cycle time} = \frac{20.238 \text{ minute}}{106 \text{ unit}}$$

Actual cycle time = 190,92 minute/unit

Calculation value of actual cycle time, performance efficiency, and quality rate for annual year can be seen at Table 8.

Than calculation of performance efficiency for March is: 74%

$$\text{Performance efficiency} = \frac{\text{Processed amount x ideal cycle time}}{\text{operation time}} \text{ x } 100\%$$

$$\text{Performance Efficiency} = \frac{106 \text{ unit x } 172{,}69 \text{ minute/unit}}{20.238 \text{ minute}} \text{ x } 100\% = 0,\ 90$$

Average of performance of efficiency is 0.87.

And rate of quality for March is found by using the formula:

$$\text{Rate of Quality} = \frac{(processed\ amount - defect\ amount)}{processed\ amount} \text{ x } 100\%$$

$$\text{Rate of Quality} = \frac{(106\ unit - 8\ unit)}{106\ unit} \text{ x } 100\%$$

Rate of Quality = 0, 92

Tabel 8. Calculation of actual cycle time and performance Efficiency for annual year

No	Month	Operation time (minute)	Processed Amount (unit)	Defect (Unit)	Actual Cycle Time (minute/unit)	Ideal Cycle Time (minute/unit)	Performance Efficiency	Rate of Quality	OEE (%)
1	March	20.238	106	8	190,92	172,69	0,90	0,92	0,78
2	Apr	20.189	102	7	197,94	173,07	0,87	0,93	0,76
3	May	19.044	95	9	200,46	173,85	0,87	0,91	0,72
4	Jun	21.062	100	6	210,62	172,68	0,82	0,94	0,71
5	Jul	15.088	81	8	186,27	172,15	0,92	0,90	0,76
6	August	21.057	97	7	217,08	172,25	0,79	0,93	0,68
7	Sept	20.184	104	9	194,07	173,16	0,89	0,91	0,76
8	Oct	20.131	99	7	203,35	173,38	0,85	0,93	0,73
9	Nov	21.025	88	12	238,92	174,59	0,73	0,86	0,58
10	Dec	19.203	106	6	181,16	168,92	0,93	0,94	0,82
11	Jan	20.212	110	5	183,74	172,63	0,94	0,95	0,83
12	Feb	19.145	103	6	185,87	171,74	0,92	0,94	0,80
Average							0,87	0,92	0.74

3.6 Calculation of Overall equipment effectiveness (OEE)

Ideal condition of OEE is:

1. Availability ≥ 90%
2. Performance Efficiency ≥ 95%
3. Rate of Quality ≥ 99%

Formula for OEE is:

OEE (%) = Availability (%) x Performance efficiency (%) x Quality rate

Calculation OEE for March is:

OEE (%) = Availability (%) x Performance efficiency (%) x Quality rate (%)

OEE = 0, 93 x 0, 90 x 0, 92

OEE = 78%

Average value of OEE is 0.74 and for annual year can be seen at Table 8.

4. Conclusions

From the data processing result with the calculation of availability, performance efficiency, and quality rating, overall equipment effectiveness value (OEE) for annual years can be determined, 74%. Based on the ideal value standard of the Japanese Plant Maintenance Institute (JIPM) is 85%, the value of OEE 74% is considered as reasonable, but indicates that there is substantial space for improvement. The OEE 74% value should be increased by 11% so the production is considered as world class. There are three factors that affect the value of OEE, there are as follows: the value of CNC Milling Machine availability is 93%, the performance of efficiency value of CNC Machining machine is 87% and CNC Milling machine rate of quality is 92%.

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