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Determination of Critical Machine using Overall Equipment Effectiveness

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Abstract— *Today, industries around the world spend a lot of money on buying new machinery to increase the production, however a little is done to get hundred percent output from the machines. Frequent machine breakdowns, tool failures, low plant availability and increased rejection are a great threat to increase operating cost and lower productivity. Overall equipment effectiveness (OEE), which shows the total efficiency of plant plays an important role in the industry. It calculates the percentage of actual effectiveness of the equipment considering availability of the equipment, performance rate when running and the quality rate of the manufactured product measured over a period of time. The purpose of this paper is to determine critical machine on a shop floor in a manufacturing plant using OEE.*

***Keywords—* machine breakdown, OEE, critical machine, availability, performance, quality.**

I. INTRODUCTION

In today's industrial scenario huge losses occur in the manufacturing shop floor. This waste is due to operators, maintenance personal, process, tooling problems and non-availability of components in time etc. Other forms of waste include idle machines, idle manpower, breakdown of machine, rejected parts etc. In this situation, a revolutionary concept of Overall Equipment Effectiveness (OEE) which includes determination of critical machine on the shop floor, has been adopted in many industries across the world to address the above said problems. This research work is based on determination of critical machine in terms of overall equipment effectiveness. For this purpose a medium scale industry in Vasai is selected known as Naminath Engg. Pvt. Ltd. It is a leading manufacturer of precision turned &cold forging components, automobile spare parts and various other components like studs, taper plugs, banjo bolts, dowel pins, pins, nuts, shafts, screws, adapters, connectors, bushes, spacer, filler & magnetic plugs. Overall equipment effectiveness (OEE) is a term coined by Seiichi Nakajima. It provides a way to measure the effectiveness of manufacturing operations from a single piece of equipment to an entire manufacturing. OEE is an effective tool used in TPM and Lean Manufacturing as a Key Performance Indicator. It is percentage of planned production time which is truly productive. OEE measurement is essential for every organization committed to eliminate waste & losses through implementation of TPM.

The losses are divided into six major categories, which affect the overall performance of the equipment namely:

1. Equipment failures/breakdown losses are the time losses as a result of sudden breakdown in machines.

2. Set-up and adjustment losses or planned downtimes are defined as time losses resulting from downtime and defective products that occur when production of one item ends and the equipment is adjusted to meet the requirements of another item.

3. Idling and minor stop losses occur when the production is interrupted by a temporary malfunction or when a machine is idling.

4. Reduced speed losses refer to the difference between equipment design speed and actual operating speed.

5. Reduced yield losses or rejects on startup occur during the early stages of production from machine start up to stabilization.

6. Quality defects or production defects and reworks are losses in quality caused by malfunctioning of production equipment.

Thus OEE is a function of the three factors namely availability, performance and quality.

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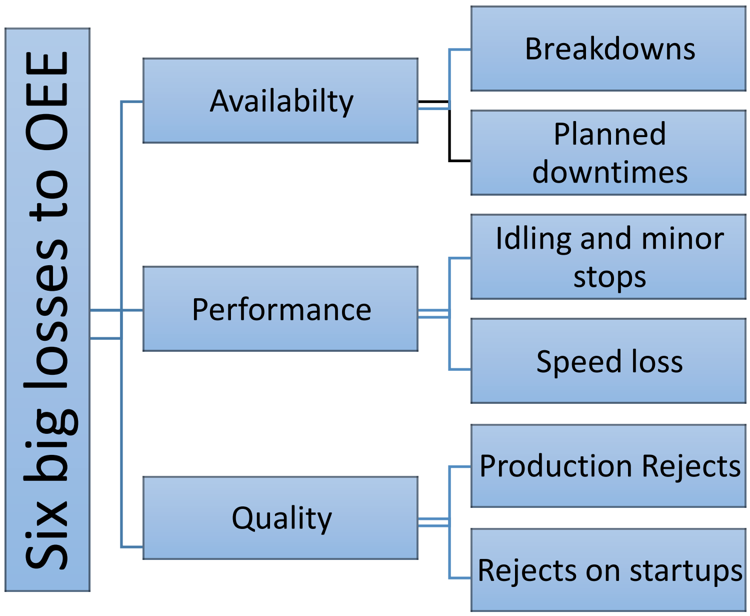

Fig.1 Losses to OEE

- **Availability**

Availability (A) of the machine is proportion of time machine is actually available out of time it should be available.

$$\text{Availability} = \frac{\text{(Planned production time – unscheduled downtime)}}{\text{Planned production time}}$$

Availability losses include equipment failures and changeovers indicating situations when the line is not running although it is expected to run.

- **Performance**

Performance (P) of the machine is the speed at which work centre runs.

$$\text{Performance} = \frac{\text{Ideal cycle time x Parts produced}}{\text{Available time}}$$

Performance losses include Speed losses, small stops, idling, and empty positions in the line, indicating that the line is running, but it is not providing the quantity it should.

- **Quality**

Quality (Q) is percentage of good parts out of total produced parts.

$$\text{Quality} = \frac{\text{(Total units started-Defective units)}}{\text{Total units started}}$$

Quality losses refer to the situation when the line is producing, but there are quality losses due to in-progress production and warm up rejects.

Therefore **OEE= Availability** × **Performance** × **Quality**.

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II. PROBLEM DEFINITION AND OBJECTIVE OF STUDY

2.1 Problem Statement

After carrying out several visits and direct observations of machines on the production shop floor and analyzing previous machine utilization records at Naminath Engg. Pvt. Ltd it was found that machines were not operating up to its full production capacity due to continuous break down of machines. Due to this availability of machines is least which is affecting the production and ultimately efficiency of the plant. Also due to lack of operator knowledge, standardize procedures and schedules for maintaining equipment's there is speed loss which is ultimately affecting performance of machines.

Objective of Study

- The objective of this study is
- To measure Overall Equipment Effectiveness of the existing machines on the production shop floor.
- To determine critical machine whose OEE needs to be improved.
- To suggest a model to improve overall efficiency of the plant.

III. METHODOLOGY

In order to overcome the above mentioned problems a brief study was carried out. To start with, few machines were selected from the shop floor. These machines were selected on the basis of most important activities performed on the production shop floor which included bolt forming, drilling, thread rolling and surface grinding. Hence the following machines were selected for study.

Table 3.1
Machines selected for study

Sr. No.	Name of Machine	Make	Product
1	3/8 Bolt Former	National	Stud, banjo bolt, pins
2	Two Spindle Drilling Machine	Glider	Banjo bolt
3	Thread Rolling	Raco Smith	M6 to M26 Studs
4	Centreless Grinding	Satnam	Plunger, Banjo bolt, Stud

Fig.3.1: 3/8 National Bolt Former Machine

Fig.3.2 Two spindle drilling Machine (BDR-01)

Fig.3.3 Thread Rolling Machine (TR-13)

Fig.3.4 Centerless Grinding Machine (CG-01)

From the machines selected in table no 3.1 critical machine is determine by calculating OEE of all the four machines. The steps in data collection are as follows:

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- Data is collected for all the four machines and stored in excel format for a period of 22 days.
- Excel sheet for data collection includes machine name, product name, duration, observer name, date, shift length, break time, down time, total pieces and reject pieces.
- The excel sheets for all the four machines are shown below.

Table 3.2
Data collection sheet for 3/8 National Bolt Former M/C

Data Collection Before TPM Implementation						
Machine: National Bolt Former				Duration: 1/12/18 to 31/12/18		
Product: Stud M8 & Banjo Bolt				Observer Name: Akshay & Swapnil		
Sr No	Date	Shift Length (mins)	Break Time (mins)	Downtime (mins)	Total Pieces	Reject Pieces
1	12-01-2018	600	60	267	16364	0
2	12-03-2018	530	60	43	22300	0
3	12-05-2018	520	60	14	27597	0
4	12-06-2018	660	60	41	33500	0
5	12-07-2018	600	60	66	28431	0
6	12-08-2018	510	60	29	23100	32
7	12-09-2018	480	60	140	15000	0
8	12-10-2018	600	60	178	20500	0
9	12-12-2018	1200	120	105	58500	10
10	13/12/2018	600	120	428	3090	0
11	15/12/2018	600	60	213	19600	0
12	16/12/2018	1200	120	135	53100	0
13	19/12/2018	600	60	67	28350	0
14	20/12/2018	600	60	170	22200	0
15	21/12/2018	1200	120	150	52200	0
16	22/12/2018	1200	120	121	56300	0
17	23-12-2018	1200	120	158	54110	5
18	26/12/2018	600	60	148	23500	0
19	27-12-2018	540	60	120	18800	0
20	28/12/2018	1200	120	160	54000	0
21	29/12/2018	600	60	88	23500	0
22	31/12/2018	600	60	146	23600	0
	Total	**16440**	**1740**	**2987**	**677642**	**47**

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Table 3.3
Data collection sheet for Two spindle Drilling M/C BDR-01

Data Collection Before TPM Implementation						
Product: Banjo Bolt				Duration: 16/11/18 to 31/12/18		
Machine: Two spindle drilling machine BDR-01				Observer Name: Akshay & Swapnil		
Sr No	**Date**	**Shift Length (mins)**	**Break Time (mins)**	**Downtime (mins)**	**Total Pieces**	**Reject Pieces**
1	16/11/2018	720	120	354	1320	0
2	23/11/2018	720	120	354	1320	10
3	24/11/2018	720	120	350	1350	10
4	25-11-2018	720	120	350	1355	0
5	26-11-2018	720	120	354	1325	0
6	28-11-2018	720	120	350	`1345	8
7	29-11-2018	720	120	375	1265	6
8	30/11/2018	720	120	375	1260	6
9	01-12-2018	720	120	375	1262	9
10	02-12-2018	720	120	345	1370	10
11	03-12-2018	720	120	195	1790	5
12	05-12-2018	720	120	183	1810	7
13	06-12-2018	720	120	320	1570	8
14	17/12/2018	720	120	420	1030	9
15	19/12/2018	720	120	478	635	5
16	24/12/2018	720	120	437	878	7
17	26/12/2018	720	120	208	1745	0
18	27/12/2018	720	120	266	1650	10
19	28/12/2018	720	120	123	2035	10
20	29/12/2018	720	120	150	2010	6
21	30/12/2018	720	120	225	1705	9
22	31/12/2018	720	120	216	1725	9
	Total	**15840**	**2640**	**6803**	**30410**	**144**

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Table 3.4
Data collection sheet for Thread Rolling M/C TR-13

Data Collection Before TPM Implementation						
Product: M8 & M10 Stud				Duration: 15/11/6 to 31/12/16		
Machine: Thread Rolling Machine TR-13				Observer Name: Akshay& Swapnil		
Sr No	Date	Shift Length (mins)	Break Time (mins)	Downtime (mins)	Total Pieces	Reject Pieces
1	15-11-2016	720	120	0	8782	0
2	16-11-2016	720	120	0	8936	0
3	22-11-2016	720	120	0	7864	0
4	24-11-2016	720	120	0	8936	0
5	01-12-2016	720	120	0	8286	0
6	02-12-2016	720	120	0	8286	0
7	05-12-2016	720	120	0	9750	0
8	07-12-2016	720	120	0	8625	0
9	08-12-2016	720	120	30	8550	0
10	09-12-2016	720	120	0	9000	0
11	10-12-2016	720	120	120	6400	0
12	12-12-2016	720	120	10	8013	3
13	14-12-2016	720	120	0	9175	0
14	15-12-2016	720	120	10	8697	3
15	16-12-2016	720	120	15	9500	6
16	17-12-2016	720	120	30	9000	0
17	21-12-2016	720	120	150	6650	0
18	23-12-2016	720	120	15	7600	2
19	27-12-2016	720	120	10	8697	3
20	28-12-2016	720	120	10	7450	2
21	29-12-2016	720	120	45	7541	0
22	30-12-2016	720	120	0	9091	0
	Total	15840	2640	445	184829	19

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Table 3.5
Data collection sheet for Centreless Grinding M/C CG-01

Data Collection Before TPM Implementation						
Product: Plunger sleeve, M10 Stud				Duration: 15/11/18 to 31/12/18		
Machine: Centreless Grinding CG-01				Observer Name: Akshay & Swapnil		
Sr No	**Date**	**Shift Length (mins)**	**Break Time (mins)**	**Downtime (mins)**	**Total Pieces**	**Reject Pieces**
1	15-11-2018	720	120	0	4597	1
2	16-11-2018	720	120	0	4915	1
3	17-11-2018	720	120	0	4915	2
4	18-11-2018	720	120	0	3812	0
5	19-11-2018	720	120	0	4832	0
6	21-11-2018	720	120	120	3832	0
7	24-11-2018	720	120	0	3894	0
8	25-11-2018	720	120	180	3649	0
9	26-11-2018	720	120	120	3330	3
10	01-12-2018	720	120	0	4633	0
11	02-12-2018	720	120	0	3863	0
12	03-12-2018	720	120	120	3532	5
13	10-12-2018	720	120	0	4635	5
14	12-12-2018	720	120	0	4832	1
15	16-12-2018	720	120	0	4065	0
16	17-12-2018	720	120	0	4214	1
17	20-12-2018	720	120	0	4608	0
18	26-12-2018	720	120	0	3985	0
19	27-12-2018	720	120	0	4898	6
20	28-12-2018	720	120	0	4750	0
21	30-12-2018	720	120	0	4476	1
22	31-12-2018	720	120	0	4489	1
	Total	**15840**	**2640**	**540**	**94756**	**27**

- After collection of above data OEE is calculated in excel sheet which will include planned production time, operating time, good pieces, availability, performance, quality and OEE.
- The OEE calculations excel sheets for the above mentioned machines are shown below.

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Table 3.6
OEE calculation sheet for 3/8 National Bolt Former M/C

OEE Before TPM Implementation			
Product: Stud M8 & Banjo Bolt			
Machine: National Bolt Former			
Duration: 1/12/16 to 31/12/16			
Production Data			
Shift Length	16440	Minutes	
Break Time	1740	Minutes	
Down Time	2987	Minutes	
Ideal Run Rate	60	PPM (Pieces Per Minute)	
Total Pieces	677642	Pieces	
Reject Pieces	47	Pieces	
Support Variable	**Calculation**	**Result**	
Planned	Shift Length - Breaks	14700	Minutes
Operating Time	Planned Production Time - Down Time	11713	Minutes
Good Pieces	Total Pieces - Reject Pieces	677595	Pieces
OEE Factor	**Calculation**	**OEE%**	
Availability	Operating Time / Planned Production Time	79.68	
Performance	(Total Pieces / Operation Time) / Ideal Run Rate	96.42	
Quality	Good Pieces / Total Pieces	99.99	
Overall OEE	Availability x Performance x Quality	76.82	

Table 3.7
OEE calculation sheet for Two spindle Drilling M/C BDR-01

OEE Before TPM Implementation			
Product:Banjo Bolt			
Machine:Two Spindle Drilling Machine BDR-01			
Duration: 16/11/16 to 31/12/16			
Production Data			
Shift Length	15840	Minutes	
Break Time	2640	Minutes	
Down Time	6803	Minutes	
Ideal Run Rate	6	PPM (Pieces Per Minute)	
Total Pieces	30410	Pieces	
Reject Pieces	144	Pieces	
Support Variable	**Calculation**	**Result**	
Planned Production Time	Shift Length - Breaks	13200	Minutes
Operating Time	Planned Production Time - Down Time	6397	Minutes
Good Pieces	Total Pieces - Reject Pieces	30266	Pieces
OEE Factor	**Calculation**	**OEE%**	
Availability	Operating Time / Planned Production Time	48.46	
Performance	(Total Pieces / Operation Time) / Ideal Run Rate	79.23	
Quality	Good Pieces / Total Pieces	99.53	
Overall OEE	Availability x Performance x Quality	38.21	

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Table 3.8
OEE calculation sheet for Thread Rolling M/C TR-13

OEE Before TPM Implementation			
Product: M8 & M10 Studs			
Machine: Thread Rolling Machine TR-13			
Duration: 15/11/6 to 31/12/16			
Production Data			
Shift Length	15840	Minutes	
Break Time	2640	Minutes	
Down Time	445	Minutes	
Ideal Run Rate	16	PPM (Pieces Per Minute)	
Total Pieces	184829	Pieces	
Reject Pieces	19	Pieces	
Support Variable	**Calculation**	**Result**	
Planned	Shift Length - Breaks	13200	Minutes
Operating Time	Planned Production Time - Down Time	12755	Minutes
Good Pieces	Total Pieces - Reject Pieces	184810	Pieces
OEE Factor	**Calculation**	**OEE%**	
Availability	Operating Time / Planned Production Time	96.63	
Performance	(Total Pieces / Operation Time) / Ideal Run Rate	90.57	
Quality	Good Pieces / Total Pieces	99.99	
Overall OEE	Availability x Performance x Quality	87.50	

Table 3.9
OEE calculation sheet for Centreless Grinding M/C CG-01

OEE Before TPM Implementation			
Product: Plunger sleeve, M10 Stud			
Machine: Centreless Grinding CG-01			
Duration: 15/11/16 to 31/12/16			
Production Data			
Shift Length	15840	Minutes	
Break Time	2640	Minutes	
Down Time	540	Minutes	
Ideal Run Rate	8	PPM (Pieces Per Minute)	
Total Pieces	94756	Pieces	
Reject Pieces	27	Pieces	
Support Variable	**Calculation**	**Result**	
Planned Production Time	Shift Length - Breaks	13200	Minutes
Operating Time	Planned Production Time - Down Time	12660	Minutes
Good Pieces	Total Pieces - Reject Pieces	94729	Pieces
OEE Factor	**Calculation**	**OEE%**	
Availability	Operating Time / Planned Production	95.91	
Performance	(Total Pieces / Operation Time) / Ideal	93.56	
Quality	Good Pieces / Total Pieces	99.97	

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IV. RESULT AND CONCLUSION

After analyzing the above excel sheets the OEE for all the four machines are compared graphically and critical machine is determined.

Table 4.1
OEE comparisons of machines

Machine Name	National Bolt Former	Two Spindle Drilling Machine BDR-01	Thread Rolling Machine TR-13	Centreless Grinding CG-01
Availability	79.68	48.46	96.63	95.91
Performance	96.42	79.23	90.57	93.56
Quality	99.99	99.53	99.99	99.97
Overall OEE	76.82	38.21	87.5	89.71

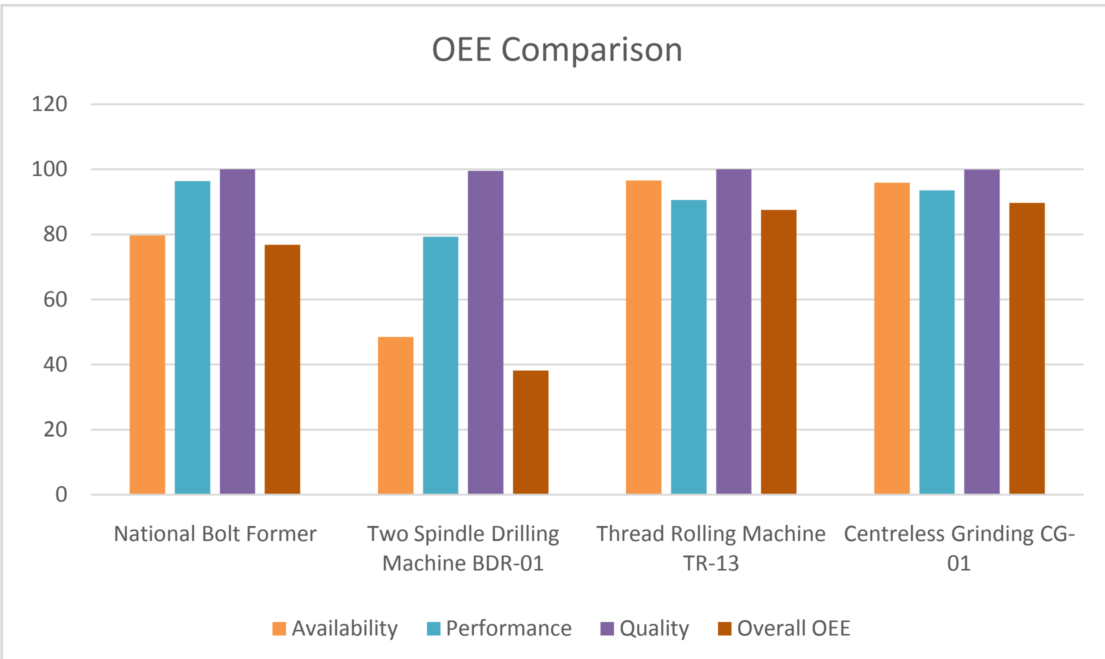

Fig.4.1 OEE comparisons of machines

From the above graph it is clear that the critical machine is Two spindle Drilling Machine (BDR-01) whose OEE is least i.e. 38.21%.This is effecting the overall efficiency of the plant and hence there is need to increase availability, performance and quality of the critical machine. Also downtime of the machine has to be improved. Thus the objective of the study i.e. determination of critical machine is accomplished. In order to enhance OEE, implementation of Total Productive Maintenance (TPM) is to be carried out on planned and regular basis. Thus after carrying out stepwise implementation of pillars of TPM in the company marked improvements in availability, performance efficiency and quality rate can be achieved thereby leading to increase in OEE of critical machine.

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