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EVALUATION OF PRODUCTION PRODUCTIVITY USING OVERALL EQUIPMENT EFFECTIVENESS

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ABSTRACT

The purpose of this paper is to evaluate production productivity by the use of the Overall Equipment Effectiveness (OEE) indicator. The OEE measures how effectively an equipment is utilized. A case study at Libyan Iron and Steel Company was conducted. The results show that the OEE for production line 2 is much better than production line1. However, the average OEE for both production lines are 67.62% and 72.79% respectively. These low values of OEE are a result mainly of the reduction in the quality rate. The average quality rate for both production lines 1 and 2 are 95.47% and 92.94% respectively.

KEYWORDS: Performance, quality, overall effectiveness, Libyan steel.

INTRODUCTION

OEE has been used extensively for measuring equipment productivity improvement. OEE was recognized as a fundamental method for measuring equipment performance from the late 1980s and early 1990s. Now it is accepted by management consultants as a primary performance metric. When it is applied by autonomous small groups on the shop-floor together with quality control tools, OEE is an important complement to the traditional top-down oriented performance measurement systems. OEE is often used as a driver for improving performance of the business by focusing on quality, productivity and equipment availability issues and hence aimed to reduce non-value activities that are often inherited in manufacturing processes.

The OEE was born as the backbone of Total Productive Maintenance (TPM) and then of other techniques employed in asset management programs, Lean manufacturing [1]. OEE measures how effective the machine is used for manufacturing in practically as opposed to in theory [2]. Availability, performance rate, and quality rate are the three important parameters which form the product of OEE [3]. The six big losses such as breakdowns, setup and adjustments, small stops, reduced speed, start-up rejects and the production rejects are the main contribution that affect the performance of the machines [4].

The OEE can be expressed as the ration of the actual output of the equipment divided by the maximum output of the equipment under the best performance condition. The aims of TPM is to achieve the ideal performance and achieve zero losses, which means no production scrap or defect, no breakdown, no accidents, no waste in the process running or changeover. However, the quantification of these accumulations of waste in time and its comparison to the total available time can give the production and the maintenance management a general view of the actual performance of the plant. Consequently, it can help to focus on the improvement of the biggest loss. Table (1) shows the six big loss category [5]. OEE approach has been widely used as quantitative tool for measuring equipment performance in industries [6].

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Table 1. Six big loss category

OEE Loss Classification	Six Big Loss Category	Computation of OEE
Availability rate	Equipment failure	Availability rate= operating time/ loading time
	Setup and adjustments	
Performance rate	Idling and minor stoppage	Performance rate= Net operating time/ operating time
	Reduced speed	
Quality rate	Defects in process	Quality rate= (processed amount- defect amount)/ processed amount
	Reduced yield	

In practice, however, OEE is calculated as the product of availability, performance and quality.
OEE = Availability × Performance Rate × Quality Rate (1)
Figure (1) shows an overview of OEE.

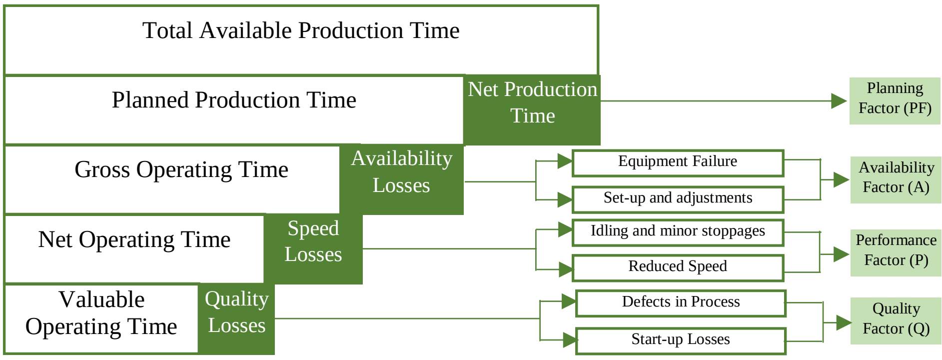

Figure1. OEE overview

CASE STUDY

The Libyan Iron and Steel Company (LISCO) is considered one of the largest industrial companies in Libya, located on an area of 1,200 hectares near the town of Misrata, just 210 kilometers to the east of the city of Tripoli.
The design capacity of the company is about 1.324 million tons of liquid steel per annum adopting direct reduction of iron pellets using domestic natural gas. On 09/09/1989, it was the opening of the production units and so the company has entered the stage of production. The study is conducted at the bars and road mill plant. The plant consists of two lines to produce bars with designed capacity of 400,000 tons of bars. The first line was commissioned in 1988 while the second line in 1989, also in 1997 double strand line was implemented, with an annual designed capacity of 400,000 tons, it has started operating in 1998.

Data analysis

The study considers the period of the first five months in 2016. The collected data is then classified and arranged in a way that can easily calculate the overall efficiency of the equipment in bars and road mill plant as shown in Table (2). This data is collected from the production and control department, maintenance department, Computerized Maintenance Management System (CMMS) and the reports issued from planning and maintenance department of LISCO related to bars and road mill plant.

Overall equipment efficiency

The OEE is described as one such performance measurement tool that measures different types of production losses and indicates areas of process improvement. The OEE is a result that can be expressed as the ration of the actual output of the equipment divided by the maximum output of the equipment under the best performance condition [6].

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Table 2. The collected data for production lines 1 and 2

	Production line 1					Production line 2				
	Months					Months				
	Jan.	Feb.	Mar.	Apr.	May	Jan.	Feb.	Mar.	Apr.	May
Production (ton)	14904.7	18386.3	15988.6	15170.9	15647.3	20303.6	20877.9	20157.6	20157.4	16056.2
Defects (ton)	597.7	790.5	419.9	641.7	1167.6	1176.2	1061.0	1643.8	814.3	1959.4
Productivity (%)	30.6	38.7	34.7	29.5	29.3	38.4	41.6	41.9	41.4	33.6
Planned Capacity (ton)	38	38	38	38	38	40	40	40	40	40
Total working hours	744	696	744	720	744	744	696	744	720	744
Operating planned (ton)	616	578	616	592	616	589	578	594	570	594

OEE calculation

As can be shown in equation (1), the OEE can be calculated by multiplying the three main factors:

[1] Availability,
[2] Performance and,
[3] Quality.

$$OEE = Availability \times Performance\ rate \times Quality\ rate \tag{1}$$

Availability

Availability is used to measure the total lost time when production line is not operating because of breakdowns, set-up adjustment and other stoppages.

The availability for both production lines is calculated as given in equation (2).

$$Availabilty = (Operating\ planned / Total\ working\ hours) \times 100 \tag{2}$$

Total working hours for each production line can then be calculated as given in equation (3).

$$Total\ working\ hours = Number\ of\ working\ days\ per\ month \times number\ of\ shifts \times number\ of\ working\ hours\ per\ shift \tag{3}$$

The results of availability for both production lines are presented in Table 3.

Table 3. Availability index for production lines 1and 2

	Production Line 1						Production Line 2					
	Months					Average	Months					Average
	Jan.	Feb.	Mar.	Apr.	May		Jan.	Feb.	Mar.	Apr.	May	
Availability (%)	82.80	82.40	82.80	82.20	82.80	82.60	79.20	79.20	79.80	79.20	79.80	79.44

Through the results in Table (3) it is noted that the average availability of production line1 is higher than production line2. However, this result is lower than the standard availability (90%) [7]. This reduction leads to the downtime of the plant about 2.22 day/month. Whereas the drop of availability of production line 2 leads to downtime of the plant up to 3.2 day/month. Equation (4) shows the calculation of the plant breakdowns.

$$Breakdowns = ((Standard\ availability - average\ availability\ of\ production\ line)/30\ days) \tag{4}$$

Figures (2) and (3) show different types of machine failures. Breakdowns due to mechanical failure constitutes 62%, 59% of the total downtime in production lines1 and 2 respectively. Whereas, electrical failures contribute 25%, 30% in production lines1and 2 respectively. Whilst the other failures ranging from 2% to 10%.

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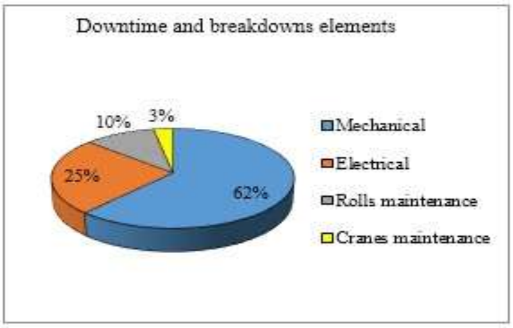

Figure 2. Downtime and breakdowns elements in production line1

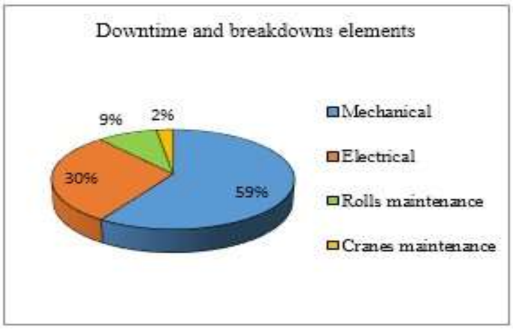

Figure 3. Downtime and breakdowns elements in production line2

Performance

The performance rate for both production lines can be calculated as given in equation (5).

$$Perormance\ rate = (productivity/planned\ production\ capacity)\times 100 \quad (5)$$

The results of performance rate for both production lines are illustrated in Table 4.

Table 4. Performance rate for production lines 1 and 2

	Production Line1						Production Line2					
	Months					Average	Months					Average
	Jan.	Feb.	Mar.	Apr.	May		Jan.	Feb.	Mar.	Apr.	May	
Performance rate (%)	80.60	*101.70	91.26	77.65	77.18	85.68	95.97	*103.90	*104.62	*103.55	84.07	98.42

From the results shown in Table (4), it is noted that the average performance rate of production line2 is much better than production line 1. Furthermore, the average performance rate of production line 2 is better than the standard performance rate (95%) [7]. It should be noted that the performance rate in February for production line1 and February, March and April for production line 2 have exceeded 100%. This is because the calculation of the performance rate was based on the production capacity rather than the design capacity of the plant. In other words, the planned production capacity was much lower than the designed capacity of the plant. This is a result from the difficulty in providing the necessary resources for the operating plant on time due to current condition of the country.

Quality

The quality rate can be expressed as the production input into the equipment minus the volume or number of quality defects divided by the production input. The quality rate can be calculated as given in equation (6).

$$Quality\ rate = (Input\ production - output\ production\ defects/Input\ production)\times 100 \quad (6)$$

Defect analysis

Types of defects that may appear in the product for the bars and road mills plant that caused rejection to the product are illustrated in Table (5).

Table 5. Types of defects in bars and road mills plant

No.	Defect name	Symbol	No.	Defect name	Symbol
1	Over unit weight	OUW	10	Bad presentation	BAP
2	Irregular lengths	IRL	11	Roll mark	ROM
3	Under unit weight	UUW	12	Dent	DET
4	Under fill	UNF	13	Over fill	OVF
5	Unsymmetrical	UNS	14	Scab	SCA
6	Overlap	OLP	15	Flat product	FLP
7	Depth of transverse ribs below standard	DTR	16	Double fins	DFN
8	Twisted product	TWP	17	Guide mark	GUM
9	Bend	Bend	18	Single fins	SFN

Figures (4) and (5) show the quantity of rejected products due to the defects that are shown in Table (5). The total of rejected products in production line1 is about 193 ton, while this quantity has increased significantly in production line 2 to reach almost 716 ton. As can be seen from figure (4) the largest amount of rejected product in production line1 due to overlap defect was about 80.53 ton. Whereas, in production line2 the largest amount of rejected product due to double fins and single fins defects are about 258 and 189 ton respectively. It should be noted that these quantities of rejected products are calculated based on data of the first five months in 2016.

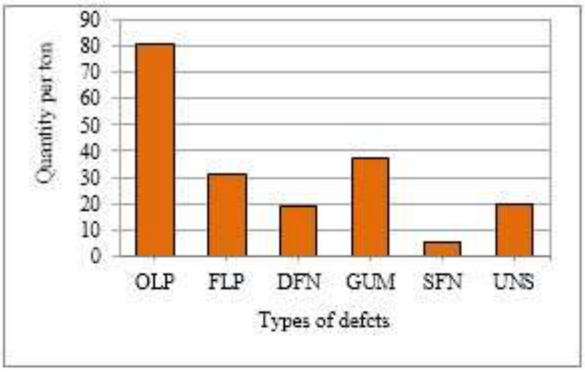

Figure 4. Quantity of rejected products in production line 1 due to defects

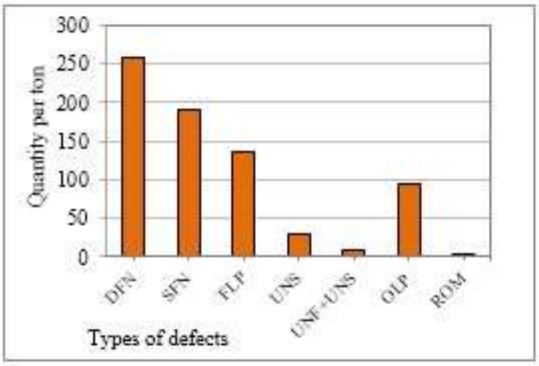

Figure 5. Quantity of rejected products in production line 2 due to defects

In addition, some products of the plant are classified as non-conforming to the specification of a specific customer order, but they can be accepted by another customer as downgrade products. For example the quantity of the product in production lines1and 2 were classified as downgrade products about 3117 ton and 6655 ton respectively. In this case, problems can be occurred in the plant in terms of rescheduling and delays in orders delivery. Moreever, the LISCO incurred financial losses as a result of the difference in the product price.
The results of quality rate for both production lines are illustrated in Table 6.
As can be seen from Table (6) the average quality rate of production line1 is better than production line2. However, the average quality rate for both production lines are much lower than the standard average quality rate (99.9%) [7]. This low percentage is a result from the highest number of defect parts that is produced by both production lines. however, this also indicates that the company management is interested more in production rather than quality.

Table 6. Quality rate for production lines 1 and 2

	Production Line1						Production Line2					
	Months					Average	Months					Average
	Jan.	Feb.	Mar.	Apr.	May		Jan.	Feb.	Mar.	Apr.	May	
Quality Rate (%)	95.99	95.70	97.37	95.76	92.53	95.47	94.20	94.91	91.84	95.95	87.79	92.94

After calculating the three main factors (availability, performance rate and quality rate), the OEE for both production lines can then be calculated using Equation (1). The results of OEE for production lines1and 2 of bars and road mills plant are illustrated in Figure (6). As can be seen from Figure (6), the OEE for production line2 is much better than production line1. Also, it was found that the average OEE for both production lines are 67.62% and 72.79% respectively. However, the OEE for production lines1and 2 are much lower than the standard OEE (85%) [7]. This reduction of the OEE is a result from the reduction in the three main factors particularly in quality rate. In addition, as can be seen from Equation (1), the OEE is based on the multiplication of the three main factors. As a result any reduction in the proportion of these factors will lead to decrease in the OEE.

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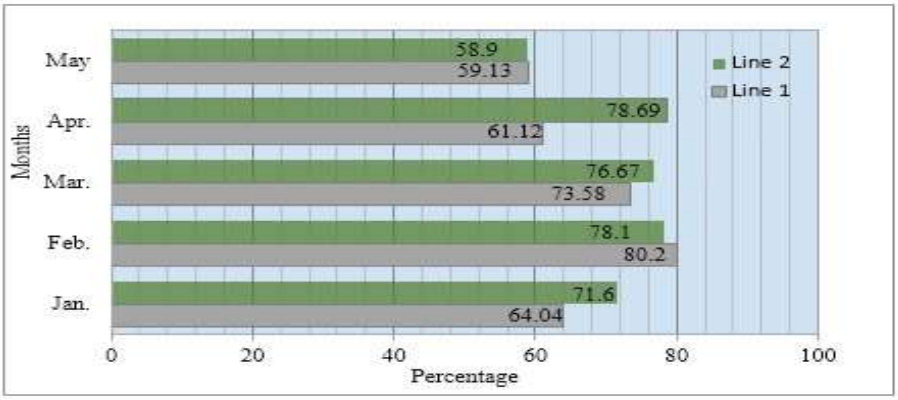

Figure 6. OEE for both production lines in LISCO

LISCO needs to work hard to improve their system machines and reduce the waste. TPM is able to eliminate the waste which does not add value to production such as waste of time and waste of material. As the company is implementing the TPM in direct reduction plant, it should expand this implementation to include bar and road mill plant. TPM seeks to minimize all the potential losses in the production and to operate the equipment with full design capacity.

On the other hand, since the company has obtained the certificate of quality management system (ISO 9001:2000) in 2002, it should reactivate it in order to keep their products under control and auditing. As mentioned previously, the average quality rate of the plant is too low, then the company should pay more attention to quality rather than focusing on production capacity only. This can be done by identifying the problems that are related to quality and causes of defect and by collecting data from their production lines for a continuous improvement. By doing all of that, breakdowns, waste of materials, waste of time and defects can then be reduced significantly. As a result the OEE of the plant can be meaningfully improved.

CONCLUSION

This study focused on evaluation of production productivity performance by using OEE. The OEE is one of widely used metrics of performance in the manufacturing. A case study in bars and road mill plant at LISCO was conducted. A quantitative measurement is applied in order to detect the effectiveness of the production lines of bars and road mill plant. The results show that OEE for both production lines1,2 are 67.62% and 72.79% respectively. The achieved results show difference between OEE in both lines and World Class Level of OEE, which is 85%. These low values of OEE are a result mainly from the reduction in the quality rate. Identification and measurement of the six big losses of the two lines were conducted in this research. These losses are mainly downtime losses, idling losses, quality losses which led to the negative effect on the OEE.

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