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Optimisation of Overall Equipment Efficiency (OEE) For A Refinery Centrifugal Gas Compressor (14k01)

Dr.Omijeh,B.O., Odor,VictorAyiri, Diei,Christopher
Department of Electrical Engineering, University of Port Harcourt UNIPORT, Choba Port Harcourt, Rivers State.
Department of Engineering Management, University of Port Harcourt UNIPORT, Choba Port Harcourt, Rivers State
Department of Mechanical Engineering, University of Port Harcourt UNIPORT, Choba Port Harcourt, Rivers State
Corresponding Author: Dr.Omijeh,B.O

ABSTRACT: *The optimization of overall equipment effectiveness (OEE) for a 14K01 refinery centrifugal gascompressor using TPM concept was carried at a gas refinery company located at Eleme in River State of Nigeria. Extracted production and Maintenance primary data was analysed using Microsoft Excel Spread Sheet to estimate the present OEE of the Wet gas compressor. The obtained results were Optimised utilising an application software called LINGO for each month.The overall Equipment Effectiveness for January was optimize from 30% to 85%, February was optimize from 27% to 88%, March was optimize from 50% to 134%, April was optimize from 34% to 93%, May was optimize from 52.3% to 104%, June was optimize from 83% to 116%, August was optimize from 19% to 59%, September was optimize from 39% to.63%, October was optimize from 26% to 86%,. Finally, December was optimizing from 25% to 86% respectively. The weighted average which represents the coefficient of the three metric (Availability, Performance Rate and Quality Rate) reveals that losses associated with Availability was the most affected followed by performance rate. Therefore, theselosses associated with availability and performance rate requires a holistic approach in terms of productive maintenance as described in generated result from Lingo and careful allocation of available resources to these two metric losses.*
KEYWORDS:*Overall Equipment Effectiveness (OEE); Availability; Performance rate; Quality rate*

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I. INTRODUCTION

The need to increase productivity in the global competitive market has raised the need for manufacturing company to redefine their manufacturing process. Although most cooperation has introduced sophisticated continuous production line to enhanced and increased production but is not sufficient to generate the performance in terms of longevity of the system. Therefore, it is necessary to introduce a performance measurement system for manufacturing processes; it is to this extent it is expedient for any cooperation to experience a marginal increase in profitability. Equipmentoptimization is inevitable as it stands to boost productivity, reduce downtime, reduced the six big loose originated from start-up delay and generally improves on the quality of the product (Ladan and Gholamreza, 2015).

In the same view Muhammad et al. (2012) explicitlydeclared their stand that in other to cease the opportunities of the market demand, theperformance rate, availability and quality rate of the product must be improved on. In the present global competitive market, it is of immense importance for manufacturing cooperation to keep update of, increase the availability of their machine and improve performance rate. The fierce battle forsupremacy of product delivery and machine capability has led manufacturing firms to solve the problem of increasing productivity. Hence manufacturing firms have resulted in increasing their work shift, acquiring new equipment's and commissioning of new sophisticated and automated production line. The core issue here is not acquiring this sophisticated equipment but the ability to improving the performance and reliability of the existing equipment's, reducing downtime, set-up time and improving the workers performance. The implementation of OEE is one of the most viable approach that can effectively evaluate and monitor the overall machine effectiveness and simultaneously simplify the complexity of production bottlenecks into simple configurations.OEE has the capacity to systematically evaluate the production process and highlights potential challenges in influencing work of the equipment. The three most influencing metrics of OEE are performance rate, quality rate and availability respectively.

Company A with 14K01 wet gas centrifugal compressor with rated capacity of 45043nm3/hr. and maximum continuous speed of 6940rpm is faced with various problems, one of which is frequent machine downtime that results in poor air quality of compressed air at the production section. Which translate to losses to the company annual income, this research work is geared towards analyzing the system configuration /process and to know the cause of frequent machine downtime implementing the six big losses concept. Although most companies are interested in OEE concept and it implementation into its maintenance management program, for this reason, many industrial companies nowadays are creating a synergy between OEE and their maintenance program simultaneously. This is one of the challenges encountered by centrifugal pump despite various attempt to deployed various concept.

The problem will be approached by developing losses associated with the three metrics then introduced the concept of OEE from the captured data necessary to compute OEE for each month. The system will be

(i) Investigated on existing methods used by the company.
(ii) Design and devise a new approach of OEE that break the information paradox.
(iii) Review new approaches and develop a model suitable for the behavior of the 14K01 wet gas centrifugal compressor.

This research work is aimed at optimizing the Overall Equipment Effectiveness of a wet gas centrifugal compressor using TPM concept.

The key objectives are:

(i) Identify the process parameters, operational rate and quality rate using OEE metric
(ii) Formulate a multi-criteria decision matrix to determine the relative weight to the main OEE metrics.
(iii) Use the weighted objective rankrelative to total productive maintenance to prioritize the losses associated withquality, performance and availability.
(iv) Improving the productivity of the system.

II. LITERATURE REVIEW

Equipment Performance rating is important in any industry and virtually most management uses performance rating as a tool to identity lapses and gaps in key areas of the manufacturing line. This relevant key performance tool is selected and designs to identify faulty mechanical parts or sub-systems that required optimization. (Weber and Thomas, 2005) Hernandez-Matias and others (2006) designed a systematic approach of evaluating the overall equipment effectiveness of a production line, they adopted the linear regression approach of estimating each metric of off and developed a linear regression model with coefficients required to check the losses associated with each metric. Anantharaman and Nachiappan (2006) developed a simple regression model for a production line that seeks to determine the overall line effectiveness using Markov Chain method. The work revealed the bottleneck associated with some particular machines subjected to overload.

Peter and Liliane (2008) views on OEE can be described as a performance tool used as a standard template to identify losses and develop necessary steps to improve on the existing or calculated company's OEE. Although they carried out a comparative analysis of total equipment effectiveness performance, production equipment effectiveness and overall equipment effectiveness and concluded that OEE still remains the most viable and effective tool for monitoring equipment responsiveness to fault detection.

David (2008) designed cost-effective models using four (4) variables, maintenance, failure rate, production and logistics, the work was simulated under a virtual environment to ascertain the influence of these variables and concluded on the premise that preventive maintenance and failure rate reduction are the two major bench-marks for achieving a cost-effective maintenance programme that describes OEE.

According to Osama and Almeanazel (2010) they described OEE as an important metric used to deductively analyze the effectiveness of total productivity management (TPM) program, which highlight the shortcomings associated with TPM program. OEE was first introduced by Nakajima, the father of Total productive Maintenance (TPM) who described OEE as a powerful equipment performance tool used for tracking work progress and improvements. In many years, it can be observed that OEE and TMP has been related in all research work, but the clear distinction between both is that OEE not only been an effective management maintenance tool but also a time dependent technique used to monitor equipment effectiveness (Williamson, 2004).

De Groote (2005) described OEE as a metric accumulated from the product of performance, availability and quality rate that calculate and monitor the actual performance of equipment relative to its capacity and capabilities under optimal operational condition. In conclusion, he described OEE as a function of machine availability which is connected to downtime losses with respect to performance rate associated with speed losses and finally product quality associated or related to quality losses.

Nazim and Others (2012) emphatically stressed the importance of the three metric parameters of OEE citing that performance cannot be a major yield stick in evaluating OEE rather machine availability and efficiency must be considered in other to achieve and meet the required world class standard of OEE. Muhammad et al (2012) investigated the efficacy of OEE on a CNC cutting section of a shipyard environment to identify and quantify losses associated with speed, quality and equipment downtime. The research work was able to recognize OEE as an important tool used by top management, but never suggested or work on optimizing OEE metric associated with quality loss and speed loss.

OEE concept was conceived and created by Nakajima in the mid 1988 which is acknowledge as one of the most powerful tool used to monitor and measure equipment performance with respect to productivity output. This concept was further developed in Japan by Japan Institute for Plant Maintenance (JIPM) which has term part of TPM methodology.

According to Hunda (2012) perception of OEE which he described as a performance evaluation tool used to determine how well equipment or production lines are properly utilized with respect to their full capacity. He further highlighted that OEE is based on three (3) fundamental metrics, performance Rate, Availability and quality rate which is used to make constraint and equipment run more effectively. Hansen (2001) view OEE as a maintenance tool used to identifies and measure losses of critical aspects of manufacturing namely performance, availability and quality rate which supports the overall improvement at equipment effectiveness and productivity

The competitiveness of any manufacturing companies depends namely on the productivity and availability of their production system. In a manufacturing setting, the quality rate, desirable productivity, cost and delivery all depend on the functionality and efficiency of the company's facilities. (Fleischer, 2006).

Lesshamimar and Jensson (1999) describe OEE as a tool used to identify losses that deduce the overall equipment effectiveness. They highlighted these losses as chronic and sporadic. The former which is associated with small and hidden losses generated as a result of several concurrent causes while the latter on the other hand are more conspicuous since they occur suddenly which can cause large deviation from the normal state. They recommended a bottom-up approach to deal with the losses associated with equipment downtime.

Huang (2003) agreed with the fact that OEE is more acceptable and is becoming increasing popular in the industry as a quantitative tool necessary for performance measurement and productivity but highlighted its limitation to productivity evaluation of individual or single equipment. Scat and Pisa (1998) acknowledge the benefit and gains of OEE implemented but reviewed its short coming on attention of individual equipment but rather focus on the overall performance of the whole production line. They therefore proposed an ultimate objective that focuses on system integration which they named overall factory effectiveness (OFE) which is aimed at combining different activities and operations of different machine and processes and integrating information across many independent subsystems and systems.

Abbas Al-Refaic and Bata (2010) introduced a concept for assessing a manufacturing process and measurement system using Gage Repeatability and Reproducibility (GR and R) adopting four quality measures. These GR and R approach helps to assess the capability of a manufacturing process and measurement system and also help in determining the necessary action for improving equipment performance.

III. MATERIALS AND METHODS

Theresearch work wasable to successfully develop an empirical model for the overall equipment efficiency of a reciprocating gas compressor through the most effective way to reduce equipment downtime and increase equipment performance. The developedmodel was able to capture the inherent losses associated with the three (3) metric (availability, quality-rate and performance rate) with respect to OEE, and then relates the six big losses which are breakdown losses, set-up and adjustment losses, start-up rejects and production rejects, reduced speed and idling and minor stoppages. A weighted objective method was used to prioritize the six big loses according to its impact on the machine effectiveness.

3.1The Three (3) Underlying Metrics

The overall equipment effectiveness (OEE) is a product of performance rate, availability and quality rate respectively.

3.1.1Availability of Equipment

Availability also referred as reliability measures the machine run time against planned production time, manufacturing firm ensures the availability of equipment or machine is at almost best. There is no benefit to having machine up and running when products are not required. However, if production rate need to be increase then obviously the equipment must meet the increase demand.

Mathematically availability can be expressed in different forms, the system, sub-system; production line in view will determine the appropriate equation necessary to evaluate the availability of the machine mathematically. Let's assume a machine is working at a particular rate then suddenly developed a fault leading to machine breakdown, which will necessitate repair of the machine, then the failure rate and repair rate in relation to the machine availability can be expressed mathematically as:

$$A = \frac{MTBF}{MTBF + MTTR} \quad (3.1)$$

$$MTBF = \frac{\sum Bi}{N_F} \quad (3.2)$$

Where MTBF, N_i and $\sum Bi$ are mean time between failure, number of occurrence and sum of machine breakdown and

$$MTTR = \frac{\sum Ri}{N_c} \quad (3.3)$$

Where MTTR, $N_c$and $\sum R_i$ are Mean Time To Repair, number of repair time and sum of machine repair time respectively.

Based on the available data extracted from the production log book we can also expressed availability as the difference uptime and downtime over up time which can be mathematically expressed as

$$\text{Availability} = \frac{UT - DT}{UT} \quad (3.4)$$

where UT, DT are Uptime and Downtime respectively.

3.1.2Performance Rate of the Equipment

The performance of equipment is usually measured by the running speed of the machine. In any manufacturing process the equipment performance serves as evaluating techniques in measuring the production rate. However, the performance of equipment is altered when the equipment is experiencing idling or time taken to make small adjustment on the equipment.

Based on this, the performance of an equipment can be expressed as the ratio of Net Run Time to Run Time while the Net Run Time can be calculated by multiplying the Total Count by Ideal Cycle Time

$$\text{Performance Rate (PR)} = \frac{NetRunTime}{RunTime}$$

Mathematically $P.R = \frac{NRT}{RT}$ (3.5)

Where $NRT = TCxICT$ (3.6)

Also, performance rate can be expressed as

$$P.R = \frac{ActualAverageProduction}{StandardProduction} x\ 100\% \quad (3.7)$$

Assume a machine used for production where the number of product produced at time (4) representing the representing the processing time at the equipment then we can express performance rate as follows:

$$P.R = \frac{NxP_t}{AcT} \quad (3.8)$$

where P.R, P_t, N, AcT are performance rate, processing time, number of product (Min) and ideal (actual operating time)

Performance rate captures two fundamental losses which will be our basis of optimization.

i. Reduced speed which captures the system operating under the required maximum permissible speed, which could be traced to machine idling, running below the required or rated speed.
ii. Minor stoppages and idling which can be traced to time lost to make minor adjustment, reconfiguration to the system or time taken for equipment to load.

3.1.3Quality Rate of Products

The core essence of any manufacturing system is its capacity to produce useful good products. If the system is available and operating at its maximum designed speed, but is producing defective products or parts, then there is no real value of operating the system. It is therefore, important to measure the quality of products with respect to system availability and performance.

Quality can be perceived as first pass yield (FPY) which defines good products that pass through manufacturing process without any hindrances or machine delay for the first time.

The quality rate cab be expressed mathematically as

$$Q.R = P.A - W.A\ /\ 100 \quad (3.9)$$

Where Q.R, P.A and W.A are quality rate, processed amount and waste amount respectively. Also, quality can be expressed as

$$\frac{T_O - P_d}{T_O} \qquad (3.10)$$

where Q.R,P_d and T_O are quality rate. Product defect and total output respectively.
Two fundamental Losses associated with Quality rate are:
(i)Production reject that deals with part do not meet the required standard in terms of quality assurance and control
(ii)Start-up rejects

3.1.4 The Concept of OverallEquipment Effectiveness (OEE)

OEE a key performance indicator that measure and monitor equipment effectiveness relative to facility productivity. It identifies the losses associated with the three (3) metric (availability, performance rate and Quality rate). Each OEE metric will be assign the weighted average percentage that is required to identify the most critical losses then sets a benchmark to measure progress in productivity with respect to equipment performance via eliminating production wastages.

$$\boldsymbol{OEE = Q.R \times P.R \times A} \qquad (3.11)$$

where OEE,P.R,Q.R and A are Overall Equipment Effectiveness, Performance rate, quality rate and Availability respectively.

3.3Optimization Model for Maximizing OEE using weighted objective approach

$$\sum_i^n \left(\frac{uptime\ - downtime}{utime}\right)_i + \left(\frac{processedamount\ \ - wasteamount}{processedamount}\right)_i + \left(\frac{actualaverageproduction}{standardproduction}\right)_i \qquad (3.12a)$$

$$\sum_i^n A_I \times Q.R_i \times P.R_I wherei = 1,2,3, \ldots \ldots \ldots \ldots n \qquad (3.12b)$$

$$\sum_i^n A_I(w_{a1}) + Q.R_i(w_{q1}) + P.R_I(w_{p1}) wherei = 1,2,3, \ldots n \qquad (3.13)$$

Subject to:

$$0 \le w_{a1} \le 1 \qquad (3.14)$$

$$0 \le w_{q1} \le 1 \qquad (3.15)$$

$$0 \le w_{p1} \le 1 \qquad (3.16)$$

$$w_{a2} + w_{q1} + w_{p2} = 1 \qquad (3.17)$$

$$A_I(w_{a1} \times w_{a2}) + Q.R_i(w_{q1}) + P.R_I(w_{p1} \times w_{p2}) \ge OEE(Classic{:}\,85\%) \qquad (3.18)$$

Using multi criteria decision making we develop a decision matrix of the order, where the relative weight to the main component of the OEE are W_{ij} = $weightedperformancevalueof\,i^{th} alternativeoverj^{th} criteria$In other to make all criteria comparable we do Normalization, Hence

Table 3.1 Weighted Averages for Performance-Rate, Quality-Rate and Availability for each Month

Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Aug**	**Sept**	**Oct**	**Dec**
	W_{ij}	W_{ij}	W_{ij}	W_{ij}	W_{ij}	W_{ij}	W_{ij}	W_{ij}	W_{ij}	W_{ij}
P.R	$\frac{x_{ij},pr}{Maxx_{ij}}$	$\frac{x_{ij},pr}{Maxx_{ij}}$	$\frac{x_{ij},pr}{Maxx_{ij}}$	$\frac{x_{ij},pr}{Maxx_{ij}}$	$\frac{x_{ij},pr}{Maxx_{ij}}$	$\frac{x_{ij},pr}{Maxx_{ij}}$	$\frac{x_{ij},pr}{Maxx_{ij}}$	$\frac{x_{ij},pr}{Maxx_{ij}}$	$\frac{x_{ij},pr}{Maxx_{ij}}$	$\frac{x_{ij},pr}{Maxx_{ij}}$
Q.R	$\frac{x_{ij},qr}{Maxx_{ij}}$	$\frac{x_{ij},qr}{Maxx_{ij}}$	$\frac{x_{ij},qr}{Maxx_{ij}}$	$\frac{x_{ij},qr}{Maxx_{ij}}$	$\frac{x_{ij},qr}{Maxx_{ij}}$	$\frac{x_{ij},qr}{Maxx_{ij}}$	$\frac{x_{ij},qr}{Maxx_{ij}}$	$\frac{x_{ij},qr}{Maxx_{ij}}$	$\frac{x_{ij},qr}{Maxx_{ij}}$	$\frac{x_{ij},qr}{Maxx_{ij}}$
A	$\frac{x_{ij},a}{Maxx_{ij}}$	$\frac{x_{ij},a}{Maxx_{ij}}$	$\frac{x_{ij},a}{Maxx_{ij}}$	$\frac{x_{ij},a}{Maxx_{ij}}$	$\frac{x_{ij},a}{Maxx_{ij}}$	$\frac{x_{ij},a}{Maxx_{ij}}$	$\frac{x_{ij},a}{Maxx_{ij}}$	$\frac{x_{ij},a}{Maxx_{ij}}$	$\frac{x_{ij},a}{Maxx_{ij}}$	$\frac{x_{ij},a}{Maxx_{ij}}$

$$W_{ij} = \frac{x_{ij}}{Maximumx\ _{ij}} \qquad (3.19)$$

w_{a1} = $Relativeweight$for**availability**withrespecttomaintenance
w_{q1} = Relativeweightfor**quality**withrespecttostart − uprejects
w_{p1} = Relativeweightfor**performance**withrespecttoproduction

3.6Input Data and System Configuration

A 14KOI wet gas centrifugal compressor with serial No. 00492 and size HC 64-8 having a rated capacity of 45043Nm3/Hrs. and maximum continuous speed of 6940rpm is used to compressed-stabilized LPG for final recovery. Primary data were extracted from the production log book of 14K01 compressor for one (1) year (2017). The system configuration with primary data obtained from the production log book was estimated using Microsoft Excel Sheet as shown in Table 4.1 below as summarized for quality-rate, availability and Performance rate. The generated results shall be a guide to maintenance engineer and contribute to overall productivityof the firm.

Table 4.1: Availability, Performance-Rate and Quality-Rate data for Centrifugal Compressor (14k01) for 2017

Month/OEE Metric	January	February	March	April	May	June	August	September	October	December
Planned Production Rate(m3)	119,040	107,520	119,040	115,200	119,040	115,200	119,040	115,200	119,040	119,040
Total Actual Product Rate (m3)	67,128	49,920	88,320	72,540	92,160	111,360	15,405	17,665	63,509	57,600
Defect Product Rate (m3)	3,200	2,900	5,362	4,200	5,652	6,001	103,635	97,535	2,818	3,059
Uptime(mins)	25,140	15,540	32,520	25,860	32100	40,680	6,960	10,080	22,500	22,920
Downtime(mins)	19500	24780	12,120	17,340	12,540	2,520	36,480	26,880	22,140	21,720
Availability (%)	**0.5632**	**0.6235**	**0.7285**	**0.5793**	**0.7191**	**0.9113**	**0.1602**	**0.2727**	**0.504**	**0.5411**
Performance-Rate (%)	**0.5639**	**0.4643**	**0.7419**	**0.6297**	**0.7742**	**0.9667**	**0.1294**	**0.1533**	**0.5335**	**0.4839**
Quality-Rate (%)	**0.9523**	**0.9419**	**0.9393**	**0.9421**	**0.9387**	**0.9461**	**0.9331**	**0.921**	**0.9556**	**0.9469**

IV. RESULTS AND DISCUSSIONS

The production data of 14KOI Centrifugal compressor was used to evaluate and optimize the OEE of the wet gas compressor. The company operates on three (3) shifts per day where each shift runs for eight (8) hours translating to 24hours per day. The production schedules for the 14K01 centrifugal compressor is as follows:

i. The estimated annual production of the centrifugal gas compressor was put at over 700,000m^3.
ii. The company operates on Three (3) shifts each having Eight (8) hours per shift. The respective shift is designated into three (3) schedules with each running from 6.00am-2pm, 2pm-9pm and 9.00pm-6am respectively.
iii. The production parameters estimated as the total actual product rate, sound product rate, defect product rate while maintenance parameter was estimated as Equipment downtime both were used to evaluate the performance rate, quality rate, Availability and Equipment Effectiveness of the 14K01Centrifugal gas Compressor. The evaluated metrics of OEE was finally analyzed using LINGO software.

4.1.1 OEE Input Data from the 14K01 wet gas Centrifugal Compressor

The Quality rate, the performance rate and Availability were extracted from the production log book andevaluated as shown in Table 4.1. Finally, the Equipment efficiency was estimated using Equation (3.11) which is shown in Table 4.2.

Table 4.2: OEEInput Data for 14K0I Centrifugal Gas Compressor for Numerical Analysis.

MONTH	Performance Rate (%)	Quality Rate (%)	Availability (%)	Overall Equipment Effectiveness (%)
JANUARY	0.5639	0.9523	0.5632	0.30243951
FEBUARY	0.4643	0.9419	0.6235	0.27267162
MARCH	0.7419	0.9393	0.7285	0.507667369
APRIL	0.6297	0.9421	0.5793	0.343664146
MAY	0.7742	0.9387	0.7191	0.522599841
JUNE	0.9667	0.9461	0.9113	0.833470305
JULY	N/A	N/A	N/A	0
AUGUST	0.1294	0.9331	0.1602	0.019343051
SEPTEMBER	0.1533	0.921	0.2727	0.038502322
OCTOBER	0.5335	0.9556	0.504	0.25694555
NOVEMBER	N/A	N/A	N/A	0
DECEMBER	0.4839	0.9469	0.5411	0.247934677
	0.54408	0.9417	0.56029	0.287070261

Table 4.2 shows a summary of the evaluated metrics of OEE, using Equation (3.9) to estimate Quality rate, Equation (3.7) to estimate Performance rate, Equation (3.4) to estimate Availability and Equation (3.11) to estimate OEE

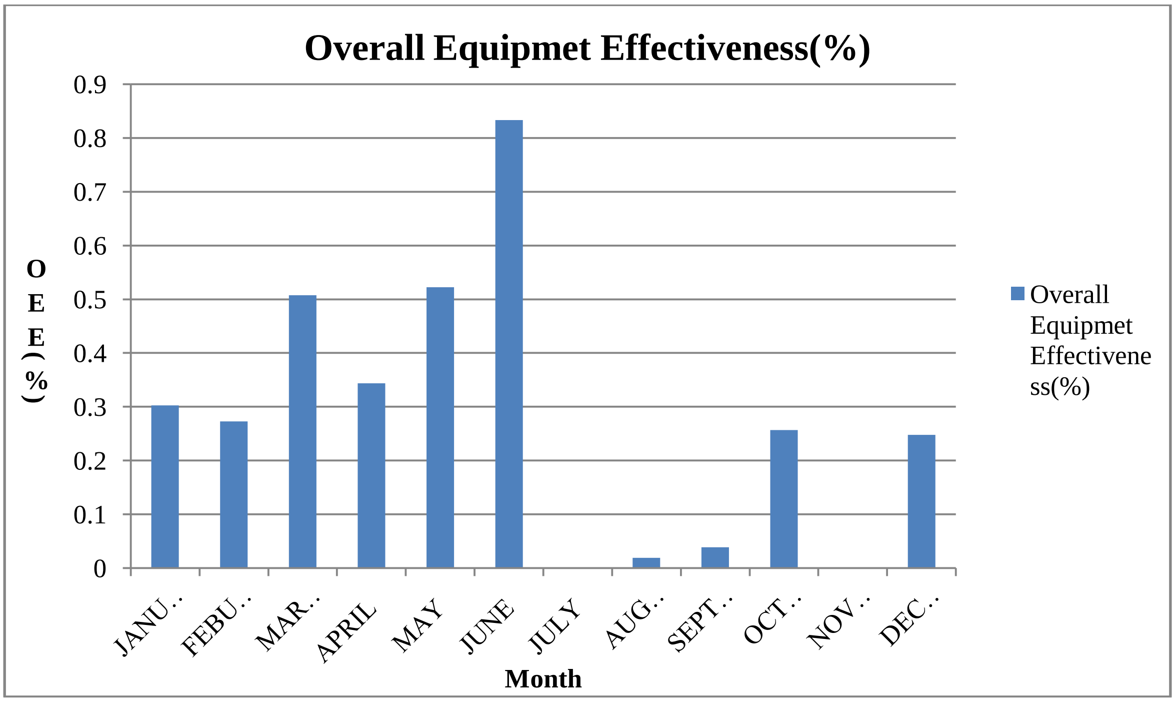

Figure 4.1: Evaluated **Overall Equipment Effectiveness for 14K01 Compressor**

Figure 4.1 shows the overall Equipment Effectiveness of an industrial 14K01 centrifugal gas compressor for different month respectively. The month of January was observed to have an OEE of 30%, then a drop to 27% in February, an increase to 51% in March, a drop in April to 34% again an increase in May and June by 52% to 83%. In July there was no production data due to general maintenance. In August to December a gradual pick of the gas compressor was noticed with an exception to the month of November due to equipment breakdown.

4.2 Optimized OEE

TABLE 4.3: Weighted Average of Performance-Rate, Quality-Rate and Availability

	W_{ij}	W_{ij}	W_{ij}	W_{ij}	W_{ij}	W_{ij}	W_{ij}	W_{ij}	W_{ij}	W_{ij}
P.R	0.0592	0.0493	0.0790	0.0668	0.0825	0,1	0.0139	0.0166	0.0558	0.0511
Q.R	0.1	0.1	0.1	0.1	0.1	0.0979	0.1	0.1	0.1	0.1
A	0.0591	0.0662	0.0776	0.0615	0.0766	0.0943	0.0172	0.0296	0.0527	0.0571

Table 4.3 results was derived from Equation (3.19), describing the weighted average for each month of the three (3) metric of OEE (Availability, Quality-rate and Performance) respectively. The weighted average gives an estimate of the relevance of each weight attached to each metric parameter (Performance rate, Availability and Quality-rate) of the OEE. From the total productive maintenance approach, it was observed that the weighted average of Availability was higher which means loses associated with availability requires a reactive maintenance approach, while the least weighted average was Performance rate which means loses associated with it means translates to low productivity.

The weighted average gives an overview of the most and least contributor of the three metric parameters. Hence, these serve as a guide to optimize the three metrics using Equation (3.12) to Equation (3.18).

TABLE 4.4: Evaluated and Optimized Overall Equipment Effectiveness

S/N	MONTH	Evaluated Overall Equipment Effectiveness (%)	Optimized Overall Equipment Effectiveness (%)
1	**JAN**	0.3024	0.8492
2	**FEB**	0.2727	0.8849
3	**MAR**	0.5077	1.34
4	**APR**	0.3437	0.9328
5	**MAY**	0.5226	1.0433
6	**JUNE**	0.8335	1.1597
7	**JULY**	NIL	NIL
8	**AUG**	0.0193	0.5892
9	**SEPT**	0.0385	0.6266
10	**OCT**	0.2569	0.8615
11	**NOV**	NIL	NIL
12	**DEC**	0.2479	0.8596

Table 4.4 shows a comparative analysis of the evaluated OEE and Optimized OEE. Table 4.2 shows the evaluated OEE before it was optimized using the weighted average approach. The weighted approach estimated the availability as the most influencing followed by performance which represents the least value generated from the weighted concept as expressed in Equation (3.19).

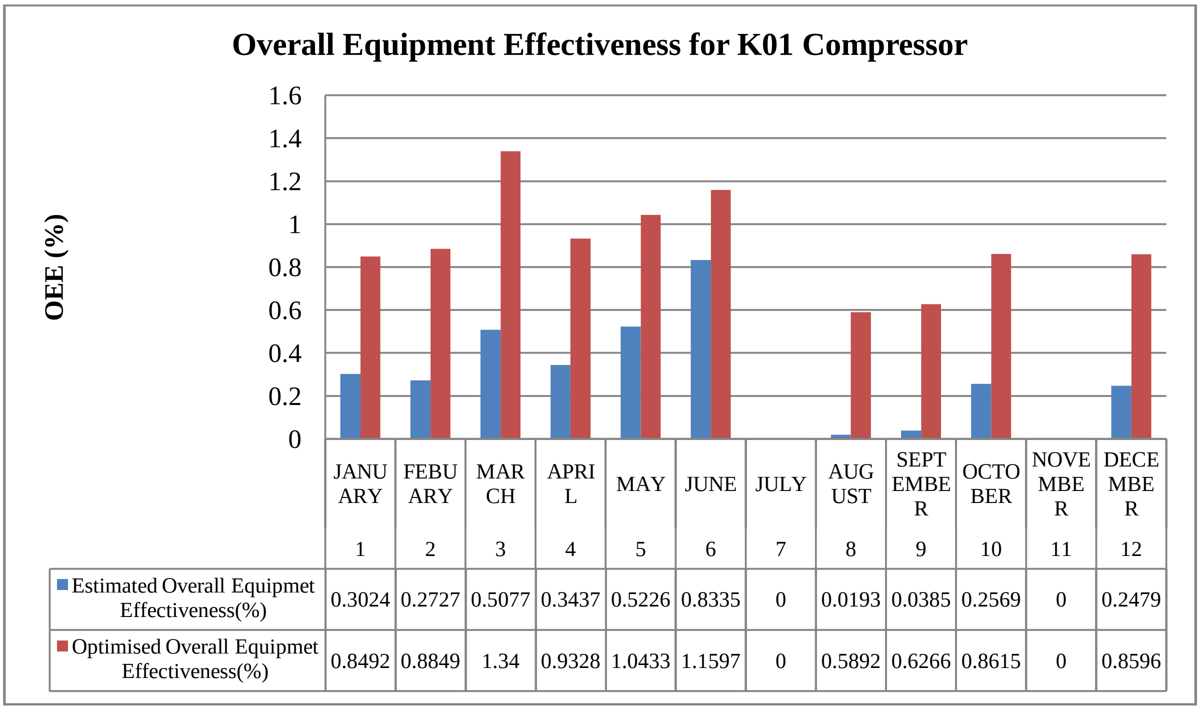

Figure 4.2: Optimized Overall Equipment Effectiveness of K01 Compressor

Figure 4.2 shows a summary of the computational results generated by LINGO application software. The weighted sum values calculated in Equation (3.19) was used to the optimize OEE using weighted objective approach for the model developed in Equation (3.12) to Equation (3.18) The overall Equipment Effectiveness for January was optimized from 30% to 85%, February was optimized from 27% to 88%, March was optimized from 50% to 134%, April was optimized from34% to 93%, May was optimized from 52.3% to 104%, June was optimized from 83% to 116%,August was optimized from 19% to 59%,September was optimized from 39% to 63%, October was optimized from 26% to 86%,. Finally, December was optimized from 25% to 86% respectively.

V. CONCLUSIONS

A 14K01 gas centrifugal compressor was analyzed using Microsoft Excel Spread Sheet to estimate the overall equipment effectiveness and observe the performance rate and availability which constitutes the most contributors to OEE. Hence, a linear program was developed using multi criteria decision of weighted objective to optimize the least and most contributors of OEE relative to their intrinsic losses.

The linear program was able to categories the losses associated with the least and most contributor of OEE and the degree of each weighted objective relative to performance rate and availability. This research work therefore concluded on the following:

(i) The overall Equipment Effectiveness of 14K01 centrifugal gas compressor was optimized for each month respectively. The month of January was optimize from 0.30% to 0.85%, February was optimize from 0.27% to 0.88%, March was optimize from 0.50% to 1.34%, April was optimize from0.34% to 0.93%, May was optimize from 0.523% to 1.04%, June was optimize from 0.83% to 1.16%, August was optimize from 0.019% to 0.59%, September was optimize from 0.039% to 0.63%, October was optimize from 0.26% to 0.86%. Finally, December was optimized from 0.25% to 0.86% respectively. The indication of this result signifies that the two major losses associated with P.R and Availability has been identified through the weighted sum average and categories according to their criticality and important in scheduling a maintenance program and allocating resources.

(ii) The developed model was able to determine the time of equipment failure and implement a productive maintenance program by determining our choice of maintenance through preventive maintenance and replacement maintenance.

(iii) In conclusion, interfacing OEE optimization with TPM concept would enhance and increases the performance of the gas compressor and categorize each loss according to the effect on OEE standard and finally design a productive maintenance program.

(iv) The overall performance of 14K01 centrifugal compressor obtained from January, 2017 to December, 2017 was underperforming. Hence, improving the effectiveness of the gas compressor would enhance an improved preventive maintenance.

5.1Contribution to Knowledge

(i) A hybrid of OEE implementation and total productive maintenance provides a strong/potent tool to evaluate losses associated with availability, quality-rate and performance rate in Port Harcourt Refinery, Operating 14K01 wet gas centrifugal compressor. This combination will provide manufacturing firms the relevance of both approaches to predict equipment performance with respect to Total Productive Maintenance.

(ii) A centrifugal compressor of any capacity but with similar design features and configuration of 14K01 wet gas centrifugal compressor can be used as a blue print to other similar compressor machine.

REFERENCES

[1]. Abbas, A. and Bata, N. (2010) evaluating measurement and process capabilities by GR and R

[2]. Abbas, A. and Bata, N. (2010). Evaluating measurement and process capabilities by GR and R with four quality measures,Journal of Manufacturing Technology Management, 43(32), 842-851.

[3]. Anantharaman, N. and Nachiappan, R. M. (2006). Evaluation of overall line effectiveness (OLE) in a continuous product line manufacturing system, Journal of Manufacturing Technology Management, 17(7), 987-1008.

[4]. David, A. (2008).Modelling, simulation and optimization of maintenance strategies under consideration of logistic processes,Swiss Federal Institute of Technology Zurich.

[5]. De Groote (2005) Performance acceleration on production machines using the overall equipment effectiveness (OEE) approach, IOP Conf. Series: Materials Science and Engineering.

[6]. Fleischer, J. (2006).calculation and optimization model for costs and effects of availability relevant services elements, in proceedings of LEC. Institute of production science, university Karlsruhe, research university, Germany.

[7]. Hasan, M. and Regina, S. (2014).Overall equipment effectiveness and overall line efficiency measurement using intelligent systems techniques, Faculty of Graduate Studies and Research,University of Regina.

[8]. Hernandez-Matias, J. C., Hidalgo, A.V.A. and Rios, J. (2006). Evaluation of techniques for manufacturing process analyses, International Journal of Manufacturing Technology, 17(4),571-583.

[9]. Huang, K. L. (2003).manufacturing productivity improvement using effectiveness metrics and simulation analysis, International Journal of Production Research 41(3):513-527.

[10]. Hunda, F. (2012). Improving the overall equipment effectiveness in high-mix-low-volume manufacturing environment, Elsevier Ltd. CIRP Analysis, 64(1), 419-422.

[11]. Ladan, H. and Hashemzadeh, G. (2015). The impact of overall equipment effectiveness on production losses in moghan cable and wire manufacturing, International Journal for Quality Research, 9(4), 565-576.

[12]. Lesshammar, M andJonsson, P. (1999). Evaluation and improvement of manufacturing,Journal of manufacturing Technology,4(3), 59-67.

[13]. Muhammad, A. S., Muhammed, R. H. and Asrafuzzaman, S.A. (2012).Analysis of performance by overall equipment effectiveness of the CNC cutting section of a shipyard, ARPN Journal of Science and Technology, 2(11), 1091-1096.

[14]. Nazim, B., Che, S.A. and Shahimi, M. (2012). Measuring oee in Malaysian palm oil mills, Interdisciplinary Journal of Contemporary Research in Business, 4(2), 733-743.

[15]. Osama, T., and Almeanazel, R. (2010). Total productive maintenance, review and overall equipment effectiveness, Jordan Journal of Mechanical and Industrial Engineering, 4(6), 517-522.

[16]. Peter, N. M. and Liliane, M. Y. A. P. (2008). Performance measurement using overall Equipment effectiveness (OEE): Literature review and practical application discussion. International Journal of Production Research, Taylor and Francis, 46 (13), 3517-3535.

[17]. Weber, A. and Thomas, R. (2005). Measuring and Managing the Maintenance Function, Reliability Practices Dofasco, Ivara Corporation, Burlington, Ontario, Canada.

[18]. Williamson, R. M. (2004). Using overall equipment effectiveness: the metric and the measure. Strategic Work System, inc., Columbus NC 28722, 1-6.

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