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Optimization of Production Processes in Imo Adapalm Nigeria Limited

AGUOCHA O. R.[1], EZEAMAKU U. L.[2], OSUEKE G. O.[3], OPARA U. V.[4]
[1] *Anambra-Imo River Basin Development Authority, Owerri*
[2] *Department of Polymer and Textile Engineering, Federal University of Technology, Owerri*
[3, 4] *Department of Mechanical Engineering, Federal University of Technology, Owerri*

Abstract- This research work focusses on the production processes in Adapalm oil mill and considers what could be done to improve the dwindling production state which has kept the company almost moribund. A study of the existing production processes was done to find out the reason(s) for low productivity in the company. Five major process points were identified as areas of setback to achieving full potentials in the factory. Models were developed. MATLAB software was used to analyse the models so as to arrive at optimal production in the system. The result of the analysis showed that the sterilizer, crane, stripper, digester and press, having exceeded their lifespan which is evident in the Mean Time Between Failure (MTBF), must be replaced and proper maintenance attitude inculcated henceforth. It is believed that when this is done, the entire system will be operating at its optimal state.

Indexed Terms- Optimization, Production Processes, Productivity, Adapalm

I. INTRODUCTION

Production is a process or procedure developed to transform a set of inputs like men, materials, capital, information, and energy into a specified set of output (Umoh et.al., (2013).

Hence, production aims at converting variety of inputs to specific output deriving utility in the process. In the light of this understanding, production planning is defined as a sequential step taken within a manufacturing setting in ensuring that strategic raw materials (materials, men, money, and machine) are available at the right time and in the right quantity to create finished products according to the schedule specified (Okah et. al., 2018). This definition implies that all activities carried out involving availability of raw materials, staff and equipment needed to create finished products in accordance with a specified schedule is production planning.

Bhaba et. al., (2015) opined that the function of production planning is based on establishing a plan, revising the plan, and adhering to the plan to accomplish desired objectives. It therefore follows that proper application of production planning techniques will help evaluate and appraise the quality and quantity of resources at input stage such as raw materials, labour data, etc. needed for production. It also helps the implementation of pre-planned process enabling optimum production. This optimization of production is the goal of all production outfits, absence of this leads to irregular operations and subsequently closure of such outfits as seen in the case of Adapalm Nigeria limited which was established in 1977 after the pattern of Kibutz farm settlement in Israel (Efosa, 2019). Adapalm has a refining capacity of 60MTPD of Olein (DeSmet, 2020), but has failed to live up to its capacity mainly due to improper management of money, materials, machines and men (Ishioma, 2020). These challenges enumerated by Ishioma (2020), are mainly as a result of poor or improper production planning. Hence, in the current bid by the present administration in Imo State to revitalize Adapalm, there is an urgent need to identify the loop holes in the production plan that led to the current moribund state of the company and hence proffer production planning procedure that will ensure optimization of production in the solutions as to how the production capacity of Adapalm can be optimized have eluded the various administrations. Production planning techniques utilized by various handlers of the company in time past has not yielded the needed results as challenges are still prevalent in the company. To this end, it is needful to carry out an assessment of the company viz-a-viz its production/work schedule, maintenance schedule, equipment/machines, palm fruit produce, etc. It is expected that an optimized production planning method will be achieved which will help to reposition the company for improved productivity.

The main objective of this study is to optimize production processes in Adapalm Nigeria The outcome of this study, when implemented will lead to improved productivity in Adapalm Nigeria Limited which will in turn increase the internally generated revenue of Imo State.

II. MATERIALS AND METHOD

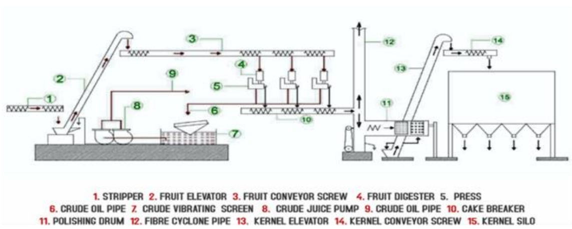

Fig. 1. Flow process diagram of Adapalm.

The sterilized fruits already detached from the stalk and emptied into the fruit stripper/ conveyor (1) discharges into the fruit elevator bucket (2) and emptied into the digester by the fruit conveyor screw (3). Meshed fruit at the digester (4) are discharged into the press (5) which squeezes out the crude juice.

While the juice is ducted through pipes (6) to the crude vibrating screen, CVS (7) the fiber and nuts are separated by gravity and cyclone action (10-12). Nuts are conveyed and stored in the silo (13-15) while fiber is conveyed to the boiler for more steam generation. The crude juice is now pumped from the CVS (7-9) to the primary/secondary decantation tanks where palm oil and sludge are separated. The oil is meant to flow through a purifier to remove every impurity/solid and then through a heater to get rid of every moisture content. Finally, it is pumped and stored in the oil storage tank ready for sales.

The materials used in this study include structured questionnaires, company quarterly/annual bulletins and oral literatures. The data collected from these materials were used for modelling and analysing the production process of ADApalm. Sources of these materials are listed as follows:

i. Records department: Information on the harvest of FFB, sale of FFB, Quantity of FFB utilized in Oil production, and Quantity of Oil produced were sourced.
ii. Production department: Information on the working drawings, work files, process operating conditions and machines specifications were obtained.
iii. Maintenance department: Information on the maintenance schedule applied in the mill section of ADApalm Nig. Ltd.
iv. Interview with production, electrical, process engineers involved in the production of palm oil in ADApalm Nig. Ltd.

- METHODS

Five process points were identified as key to maximizing palm oil production in the facility. These process points are:

i. Sterilizer; ii. Crane ; iii. Stripper; iv. Digester; v. Press .

- Sterilizer

The model was used to optimize the mass flow rate of steam needed to sterilize the FFB. Sterilizer unit model variables include the following:

Ms = Total steam mass , M_{F1} = mass of FFB
M_{F2} = mass of FFB after sterilization , C = Condensate
I = heat capacity of sterilizer unit material , t = sterilization time
U = Internal specific energy

Constraints defined for the model are as follows:
$34.9 \leq M_{F2} \leq 37.96$ $\quad C \leq 3.662$ $\quad t \leq 2700$ $\quad Ms \leq 4.66$ I = 4189 kJ/kgK
$M_{F1} = 22.5$ $\qquad Ms + M_{F1} = M_{F2} + C$ *mass conservation*
From first law of thermodynamics, we deduce that:
$Energy\ input = Energy\ output + Loss$……………………..3.1
In the sterilizer, the source of energy is the heat coming from the superheated steam.

Hence, equation 3.1 can be expressed in terms of sterilization time as:

$MsU_1 = CU_2 + M_{F2}U_2 + 15.63I$……………………………………. 3.2

From steam table, saturated steam at 275kPa will possess an internal specific energy (U_1) of 2540.53kJ/kg while steam leaving at 175kPa will possess a specific energy (U_2) of 2524.90kJ/kg. Therefore, equation 3.2 becomes:

$$\frac{2540.54Ms}{t} = 2524.90\ \frac{c}{t} + 2524.90\ \frac{Mf2}{t} + 15.63l \quad \text{……3.3}$$

Equation 3.3 is the Energy model equation needed to optimize the inlet steam flow needed for shorter sterilization time that will culminate into more production time due to time saving.

- Crane

The crane model was used to minimize the travel time needed to transport the sterilized FFB to fruit vibrating screen.

Crane unit model variables include the following:

P_c = Crane power input . M_{F2} = mass of FFB after sterilization

g = acceleration due to gravity, h = travel distance

t = travel time. Constraints defined for the model are as follows:

$P_C \leq 1100$; $h \leq 12$; $34.9 \leq M_{F2} \leq 37.96$; $g = 9.81$

Since power can be expressed as:

$$P = \frac{work\ done}{time\ taken} = \frac{F.d}{t} = \frac{mg.d}{t} \quad \text{……3.4}$$

Hence, in this context, an optimized model of the travel time can be expressed in terms of the power provided by the electric motor as:

$$t \leq \frac{9.81Mf2h}{Pc} \quad \text{……3.5}$$

- Stripper

The model was used to maximize the torque needed to detach the sterilized palm fruits from the bunch. The stripper unit model variables include the following:

P_s = Stripper power input, N = stripper motor speed

T = Stripper motor torque, ω = angular speed.

M_{F2} = mass of FFB after sterilization

In developing the required model, it is assumed that power required/delivered at the stripper shaft by the motor should exceed the power required for detaching the palm fruits. Mathematically, this is expressed as:

$$P_s \geq Pwork \quad \text{……3.6}$$

$$\frac{2\pi NT}{60} \geq \text{Mf2g.}\,\omega$$

Applying equation 3.6 to the context of the stripper optimized model, we get:

$$T \geq \frac{93.66\ Mf2\omega}{N} \quad \text{……3.7}$$

The constraints as seen in equation 3.7 are defined as follows

$500 \leq N \leq 1000$; $0.5 \leq \omega \leq 2.5$; $34.9 \leq M_{F2} \leq 37.96$

- Digester

The digester model was used to maximize the shear force needed to liberate the juice from the mesocarp. The digester unit model variables include the following:

M_{F2} = mass of FFB after sterilization h = height of digester

g = acceleration due to gravity , ω = angular velocity

D = Diameter of digester drum. Applying equation 3.6a, we get:

$$\frac{2\pi NT}{60} \geq Mf2g\omega \quad \text{……3.8}$$

But T = F.r = F. D/2. Hence, equation 3.8 becomes:

$$\frac{\pi NFD}{60} \geq Mf2g\omega \quad \text{……3.9}$$

$$F \geq \frac{20Mf2g\omega}{ND} \quad \text{……3.10}$$

Equation 3.10 gives the optimized model for the digester. Constraints for the model are defined as follows:

$500 \leq N \leq 1500$; $0.5 \leq \omega \leq 2.5$; $34.9 \leq M_{F2} \leq 37.96$; $g = 9.81$; $1 \leq D \leq 3$

- Press

The model was used to maximize the mass of palm juice expressed from the digested palm fruit by the press. In order to arrive at a model, it is assumed that the total pressure needed to extract the juice is a function the pressure exerted by the piston and the pressure due to elevation. Mathematically, this is expressed in equation 3.15 as:

P = Piston pressure + Fluid pressure………………3.11

$P = \frac{F}{A} + pgh$……………………………………3.12

$P = \frac{F}{A} + \frac{mj}{vol} . gh$…………………………………3.13

$P = \frac{mp}{A} . g + \frac{mj}{A} . g$………………………………3.14

$\therefore P = (m_p + m_j)\ (g/A)$……………………………3.15

$m_j \geq \frac{Pg}{A} - m_p$…………………………………………… 3.16

The model variables include the following:
m_j = mass of palm juice, m_p = mass of piston
g = acceleration due to gravity, P = Press pressure
A = cross sectional area of press. Constraints of this model are as follows:
$70 \leq P \leq 85$; $20 \leq m_p \leq 35$; $g = 9.81$; $A = 1.96$

- Data analysis

Data collected from the maintenance department from the January 1999 to January 2020 was used to determine the reliability of the existing machines used in the facility. These data were based on the five identified process points that play major roles in the production of palm oil in the mill. These points as enumerated earlier are steriliser, crane, stripper, digester and the press. The reliability study examines the longevity and dependability of the machines. Factors considered include the following: Failure rate, mean time between failures (MTBF), and reliability prediction using Weibull distribution.

Failure rate: The total number of failures within an item population, divided by the total number of life units expended by that population, during a particular measurement interval under stated conditions. It is estimated using equation 3.17.

$\lambda = r / T$……………………………………… (3.17)

where λ = failure rate, r = the total number of failures occurring during the investigation period, T = Total running time during an investigation period for both failed and non-failed items. Mean Time Between Failure (MTBF): MTBF is a basic measure of reliability for repairable items. It represents the mean number of life units during which all parts of the item perform within their specified limits, during a particular measurement interval under stated conditions. It is expressed mathematically using equation 3.18

$\theta = 1 / \lambda$……………………………………… (3.18)

Reliability Prediction: This was carried out using Weibull distribution to first determine the probability density function (failure frequency distribution) of a set of failure data in order to characterize the failures of the various machines in the mill as early life, constant (exponential) or wear out (Gaussian or log normal) by plotting time to failure data with the log of the time to failure plotted a log scaled X-axis versus the cumulative) percent of the population represented by each failure on a log-log scaled Y-axis. Since production process is majorly affected by these five process points, the overall system reliability was calculated by first determining the reliability of the subsystems using the formulae stated in equation (3.19).

$R(t) = e^{-(\frac{t}{\eta})^{\beta}}$………………………………… (3.19)

Where:
β = Shape parameter of the Weibull plot
t = Failure time being considered
η = Characteristic life

β shows the class of failure mode i.e infant mortality, constant or wear out. It is obtained from the slope of the Weibull plot.

η shows the age (time) at which 63.2% of the unit will fail. It is obtained at the point on the time axis which corresponds to the point on the graph where the 63.2% line on the y axis meets on the graph.

The overall system reliability which gives the longevity and dependability of the system was analysed as a series system because the operation is such that subsystem A is followed by subsystem B. Hence, a breakdown in subsystem A will affect the running of subsystem B. Equation (3.20) was used to determine the reliability of the system.

$Rs_{(t)} = R1_{(t)} \times R2_{(t)} \times R3_{(t)} \times R4_{(t)} \times R5_{(t)}$……………………………………(3.20)

The failure rate of the major process points was determined using equation 3.17.

Failure rate of Sterilizer: From figure 2, it is observed that on the average, the number of failures experienced within an average of 21633.42 hours is 9.36538E-08, this means that equipment failure is recorded at least once in every 494 hours of operation.

Data obtained from the failure rate and the time to fail was used to plot the 'bath tub' curve of the sterilizer, as seen in figure 2.

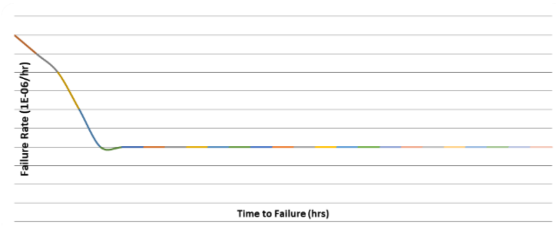

Figure 2: Sterilizer Bathtub Curve

This curve as opined by Troyer, (2020) is instructive to effectively demonstrate a machines three basic failure characteristics viz: declining, constant and increasing. These characteristics correspond to infant, constant and wear out failures. we observe that the sterilizer is currently at its constant/low failure rate indicating that there is no increase in the frequency of failure occurrence; hence stable operation of the equipment can be inferred.

Failure Rate of Crane: The average failure rate for the period under investigation is 8.23191E-08. This implies that the average number of failures witnessed by the machine within the period of 25101.44681 hours is 0.00206633, and for every 8760 hours of operation, failure is experienced at least 18 times.

Failure Rate of Stripper: The stripper has an average failure rate of 1.14615E-07 over an average failure time of 21633.42 hours. This means that failure was experienced 21 times in every 8760 hours of operation.

Failure Rate of Digester: The average failure rate over the investigation period is 9.36538E-08 implying that the machine experiences breakdown 24 times in every 8760 hours of operation.

Failure Rate of Press: The average rate of failure over the period under observation is given as 0.12212766 . This means that on the average, the equipment experiences 27 breakdowns in 8760 operation hours.

Table 1. Technical Data Collected on the MTBF of Machines

Machine	MTBF (hrs)
Sterilizer	10,000,000
Crane	15,000,000
Stripper	35,000,000
Digester	10,000,000
Press	20,000,000

(Source: Records Department, 2019)

The failure rate of the respective machines can be found using equation (3.17).

Table 2: Comparison Between Machines Rated Failure Rate Before Use and During Use

Machine	MTBF (hrs)	Failure Rate (Rated Value)	Failure Rate (Service Life Value)
Sterilizer	10,000,000	0.0876%	0.0815%
Crane	10,000,000	0.058%	0.07%
Stripper	35,000,000	0.025%	0.0876%
Digester	10,000,000	0.0876%	0.0815%
Press	20,000,000	0.045%	0.0876%

The table reveals that with the exception of the sterilizer and digester, all other machines analysed had failure rates exceeding the expected value as stipulated by their respective manufacturers. These higher failure rates are mainly associated with inadequate/poor/improper maintenance schedules/practices, leading to more failure than expected and finally quicker/faster advancement into the worn out phase.

Sterilizer Optimization
The linear programme (m-file) for the optimization of the crane was written using MATLAB.

Crane Optimization
The linear programme (m-file) for the optimization of the crane was written using MATLAB.

Digester Optimiz The linear programme (m-file) for the optimization of the digester was written using MATLAB. The result shows that for the optimal running of a digester should not have a shear force less than 1.4938 kN

Press Optimization

The linear programme (m-file) for the optimization of the digester was written using MATLAB. The result shows that the press is capable of producing a maximum of 198.8289 and a minimum of 120 tonnes of palm juice if the piston used will have a mass of 83.7810 kg and operate at 67.3905 N/m^2.

CONCLUSION

This work has shown that instead of continuous wasting of money on repairs and loosing of man-hours due to down time, it will be better to replace the machines of some strategic process points for higher productivity. When the satisfaction derived from a machinery becomes less than its cost of maintenance, replacement becomes inevitable so that productivity will not be negatively impacted. The reliability values of 3.9%, 0.1%, 6.1%, 6.1%, 0.4% for Sterilizer, crane, stripper, digester, and press respectively show that it is rather in the worn out region, and they depict poor management, misuse or abuse of the production equipment.

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