Optimization of the Digester Unit in Imo Adapalm Nigeria Limited

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Abstract- This research work focuses on the Digester unit processes in Adapalm oil mill and considers what could be done to improve the dwindling production state and its environmental impact, on host Communities on one hand, and how it has kept the company almost moribund. A study of the existing digesters was done to find out the reason(s) for low productivity in the company. 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 digesters, 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, a cleaner environment will also be achieved, leading to overall productivity improvement.

Indexed Terms- Optimization, Digester, Productivity, Adapalm, Environmental Impact.

I. INTRODUCTION

It is believed production is a process or procedure for transforming 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. In such planning, every product or, and wastes must be controlled properly, to ensure environmentally friendly operations.

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 unacceptable state of the company and hence proffer production planning procedure that will ensure optimization of production. In the same effort, solutions as to how the production capacity of Adapalm can be optimized have eluded the various administrations before now. 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 the Digesters 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

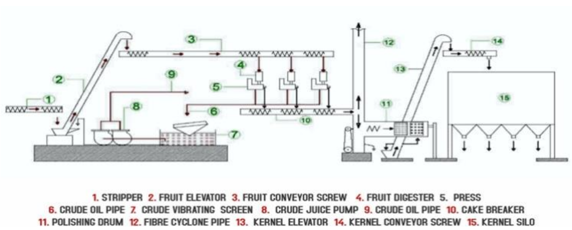


Fig. 1. Flow process diagram of Adapalm.

- Brief explanation of the flow diagram

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:

Currently, the crude juice extraction rate is 17 – 18% of every 100 tonne of FFB processed and the amount of palm oil produced from this percentage is 2.25 tonne. Therefore, in a bid to optimize the production of palm oil, it is pertinent to carry out a reliability study of the existing machines used in production. This revealed the current state of the machines and the areas where optimization study should be aimed at.

- Development of the models

The Digester is one major process points identified as key to maximizing palm oil production in the facility. Modelling the digester is therefore paramount in devising ways for this optimization of the processes. Also, monitoring and controlling all posible areas of leakages into the environment were considered.

- 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:

$$\frac{2\pi NT}{60} \geq Mf2g\omega \quad \ldots\ldots 1$$

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

$$\frac{\pi NFD}{60} \geq Mf2g\omega \quad \ldots\ldots 2$$

$$F \geq \frac{20Mf2g\omega}{ND} \quad \ldots\ldots 3$$

Equation 3 gives the optimized model for the digester. Constraints for the model are defined as follows:

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

- 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, of which the digester is one. 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 4

$$\lambda = r/T \quad \ldots\ldots 4$$

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 5

$$\theta = 1/\lambda \quad \ldots\ldots 5$$

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 6.

$$R(t) = e^{-\left(\frac{t}{\eta}\right)^{\beta}} \quad \ldots\ldots 6$$

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 7 was used to determine the reliability of the system.

Optimization Study:

Equation 7 was used to determine the reliability of the system.

$$Rs_{(t)} = R1_{(t)} \times R2_{(t)} \times R3_{(t)} \times R4_{(t)} \times R5_{(t)} \quad \ldots\ldots 7$$

The production department was applied to the developed optimization models using the MATLAB optimization tool in order to arrive at optimum conditions needed for increased output. The developed optimization models also agreed with available safety standards for achieving acceptable environmental impact in the industry.

III. RESULT AND ANALYSIS

ADApalm currently has 398 employees 120 questionnaires were sent to be filled by these employees. 81 questionnaires were filled and returned 31 were not returned. This amounts to 20% of the

population size which GreatBrook, (2022) showed will give a mean score which lies between +/- 10% at 95% accuracy. With this established, data collected was then analysed to determine the failure rate, mean time before failure (MTBF) of the machines, reliability prediction, reliability estimate for the possible number of years left for the machine to run.
Failure Rate

The failure rate of the major process points was determined using equation 4.

Failure Rate of Digester: Figure 2 shows that 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. The bathtub curve in figure 2 depicts a machine that is currently experiencing a low or relatively constant failure rate mainly as a result of working stress exceeding material strength.

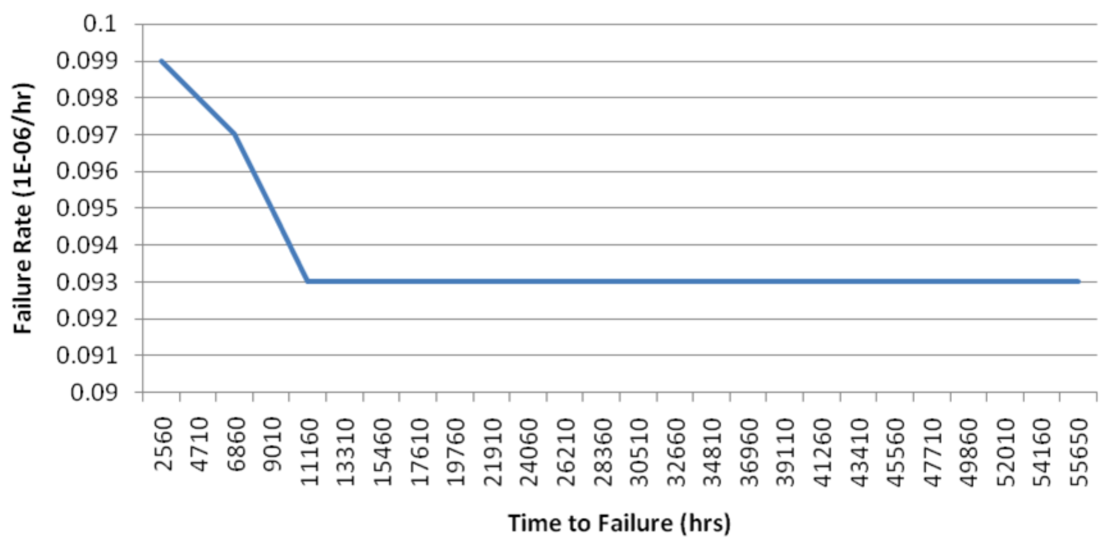
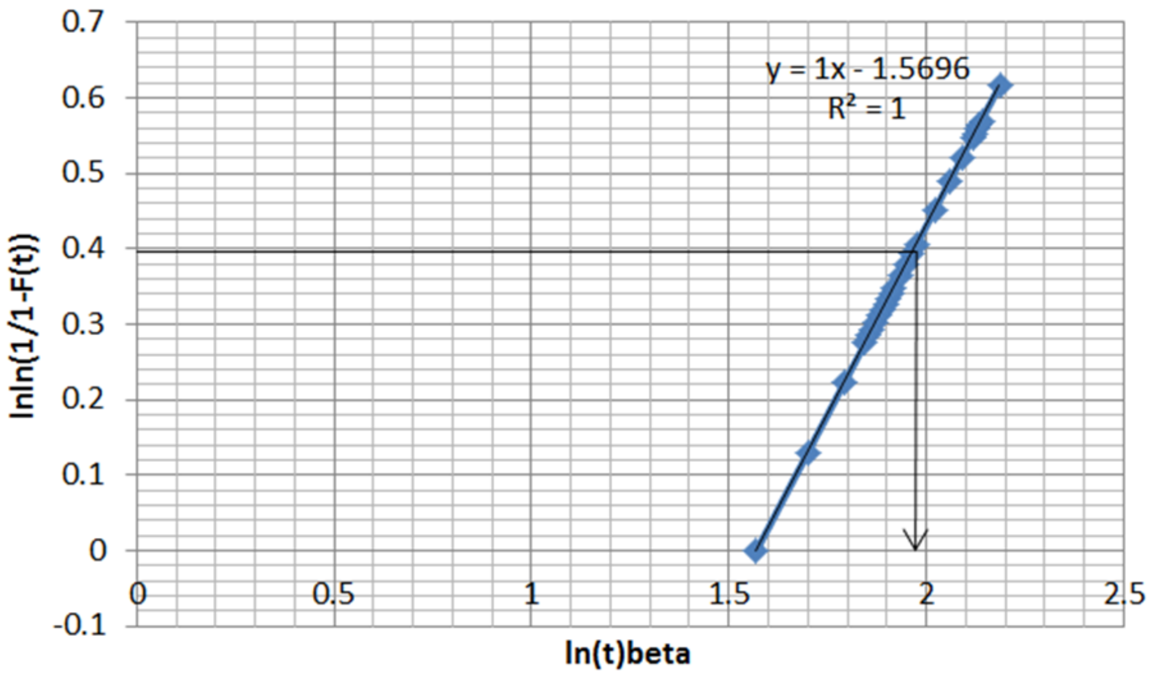


Figure 2: Bathtub Curve of Digester

However, it is clear from figure 2 that the equipment is still within its normal life and fatigue or depletion of materials which precede wear out have not set in.

Digester Optimization. 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, it should not have a shear force less than 1.4938 kN.



Fig, 3: The Weibull plot of the Digester.

The Weibull plot of the digester was seen to be similar with that of the stripper. An explanation to this could be that both have the same mode of operation i.e an electric motor which revolves a shaft connected to it. Hence, the same handling was experienced by both equipment. From the plot, η which corresponds to the time at which 63.2 % failure in the equipment occurs is 19930.37 hrs. The shape parameter of the plot is 1. According to Abernethy (2010), when β = 1, then the system experiences random failure. This could be as a result of Maintenance errors, human errors, poor environmental protection, abusive events etc.

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 value of 6.1%, for Digester, poor environmental safety outlay, show that it is rather in the worn out region, and depicts poor management, misuse or abuse of the production equipment.

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