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Predicting Flights Wear in Screw Presses in Palm Oil Mills

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ABSTRACT

The wear trend of flights in twin screw presses in oil palm mills has been examined, using Rison Palm Oil Mill in Rivers State of Nigeria as a case study. Measurements were made to generate data for modeling purposes. Flights wear rates at varying press speeds and throughput capacities were measured. Multiple regression analyses were made to determine the best predicting model. The multiple regression double-log model was found the best fitting model for wear prediction in the system.

Keywords: *Twin-Screw Press; Wear Prediction; Flights; Press Speed; Throughput Capacity; Regression Models.*

1. INTRODUCTION

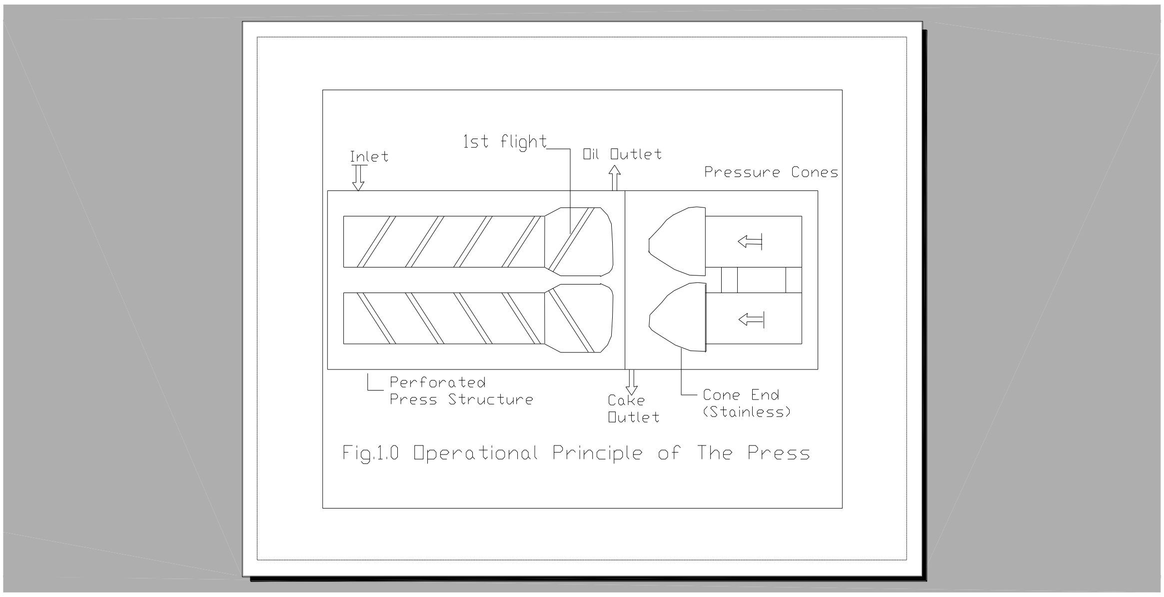
Wear prediction in screw presses is usually difficult owing to too many influencing variables to contend with; such variables as load, speed, screw material, in-process material, surface finish as well as operating and environmental factors, comprising the presence of abrasive contaminants, corrosives, vibration, etc. One also needs to know how these factors interact in order to get the best of wear predictions (Khurmi, 2004). In modeling the prediction of wear in screw presses, it thus becomes necessary to categorize the above influencing factors in terms of (i) major factors, which include the load or throughput capacity, as well as the speed, and (ii) minor factors , which covers all the remaining variables.

The choice of tribological materials of construction is a critical factor for press screws (Kragelsky, 1981). It is however assumed that whilst the best of engineering material is selected, usually based on surface hardness (manganese cast steel, for instance.), the press screw speed and the throughput capacity exert the greatest influence on the wear of the flights. There can be no question of poor lubrication since enough oil from the in-process material (the digested material in the oil mill) invariably accounts for that. The model can therefore be generalized to include (Mendenhall, 1981): (i) the deterministic part, which takes care of the major variables or determinants; and (ii) the random error part, which takes care of other minor variables.

Several models were employed in an attempt to determine the best combinations of the press screw speed, N and the throughput capacity, Q that will guarantee a minimum wear of the flights.

2. OPERATIONAL PRINCIPLE

Figure 1.0 illustrates the operational principle of the press. Two screws of progressively reducing pitch are caused to rotate oppositively inside a screen surface. Material entering the hopper is subjected to gradually increasing pressure as it moves toward the exit end of the press, thereby forcing the liquid phase to extrude through the screen. Final pressing is usually controlled by a pneumatically actuated cone that provides easy adjustment of moisture content. Wedge wire screens and hard surfaced wear areas are standardized. Outstanding characteristics of the twin screw press include tight squeezing automatic control, positive feeding, and low horsepower. Two discharge cones actuated by air cylinders allow consistent performance over a wide range of flow rates and consistencies. The twin screw press is used to extract palm oil from the digested matrix (consisting of the oil bearing flesh, kernel nut and palm fruit fibers). Palm fruits are normally plucked from trees in bunches (Hartley, 1977). These are sterilized, debunched and digested. The digested matrix is fed into the screw press where it is squeezed in-between screws rotating in opposite directions and oil is drained from the bottom of the machine.



3. FUNCTIONAL WEAR RATE

In order to examine the wear behaviour in the twin screw press measurements on the flight thickness were taken at one week intervals on each of the five flights of the screw covering a period of six (6) months. Fig. 2.0 shows the wear trends of the five flights.

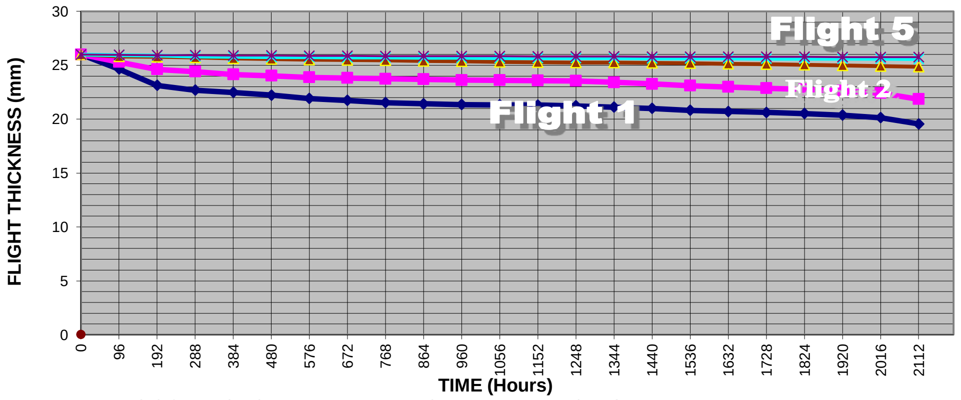


FIG.2.0 FUNCTIONAL WEAR RATE OF THE FIVE FLIGHTS

4. METHODOLOGY

Measurements were taken to generate data for the analysis. The press screw speed was varied by the use of a variable speed pulley system. The throughput capacity was computed from timed samples of the press cake and drained oil. The average thickness and hence the wear of the flights were recorded over time from which was calculated the average wear rate of the flights at different speeds and throughput capacities. Data obtained were used for the regression analyses.

5. Multiple Regression Analysis

Several regression models were constructed to examine the combined effect of the throughput capacity and the press speed on the wear rate of the flights. This is aimed at obtaining the best prediction model for the flights wear rate in the twin screw press.

5.1 Multiple Regression Linear Model of Press Speed and Throughput Capacity

First, a linear model was constructed to examine the combined influence of the throughput capacity and the press speed on the wear rate of the flights. Table 1.0 shows the SAS (Statistical Analysis System) printout, while Fig.3.0 gives the response curve of the model. The computer printout gives the model equation as:

Y = 1.123559E-9 + (2.08893E-10)N – (0.00000122)Q (1) where Y is wear rate of flights

5.2 Multiple Regression Exponential Model of press Speed and Throughput Capacity

An exponential model was also considered. Table2.0 shows the SAS printout, while Fig.4.0 shows the response curve of the model. From the computer printout, the model equation becomes;

ln(Y) = -20.46383 + (0.26040)N – (1564.32274)Q (2)

Table 1.0 SAS printout for multiple linear model of N and Q

The REG Procedure

Dependent Variable: y y

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	9.11505E-20	4.55752E-20	131.69	0.0002
Error	4	1.38437E-21	3.46093E-22		
Corrected Total	6	9.25349E-20			

Root MSE	1.86036E-11	R-Square	0.9850
Dependent Mean	9.53143E-10	Adj R-Sq	0.9776
Coeff Var	1.95181		

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	Intercept	1	1.123559E-9	5.05343E-10	2.22	0.0903
n	n	1	2.08893E-10	1.16176E-10	1.80	0.1466
q	q	1	-0.00000122	8.561572E-7	-1.42	0.2276

Table 2.0 SAS printout for multiple exponential model of N and Q

The REG Procedure

Dependent Variable: y y

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
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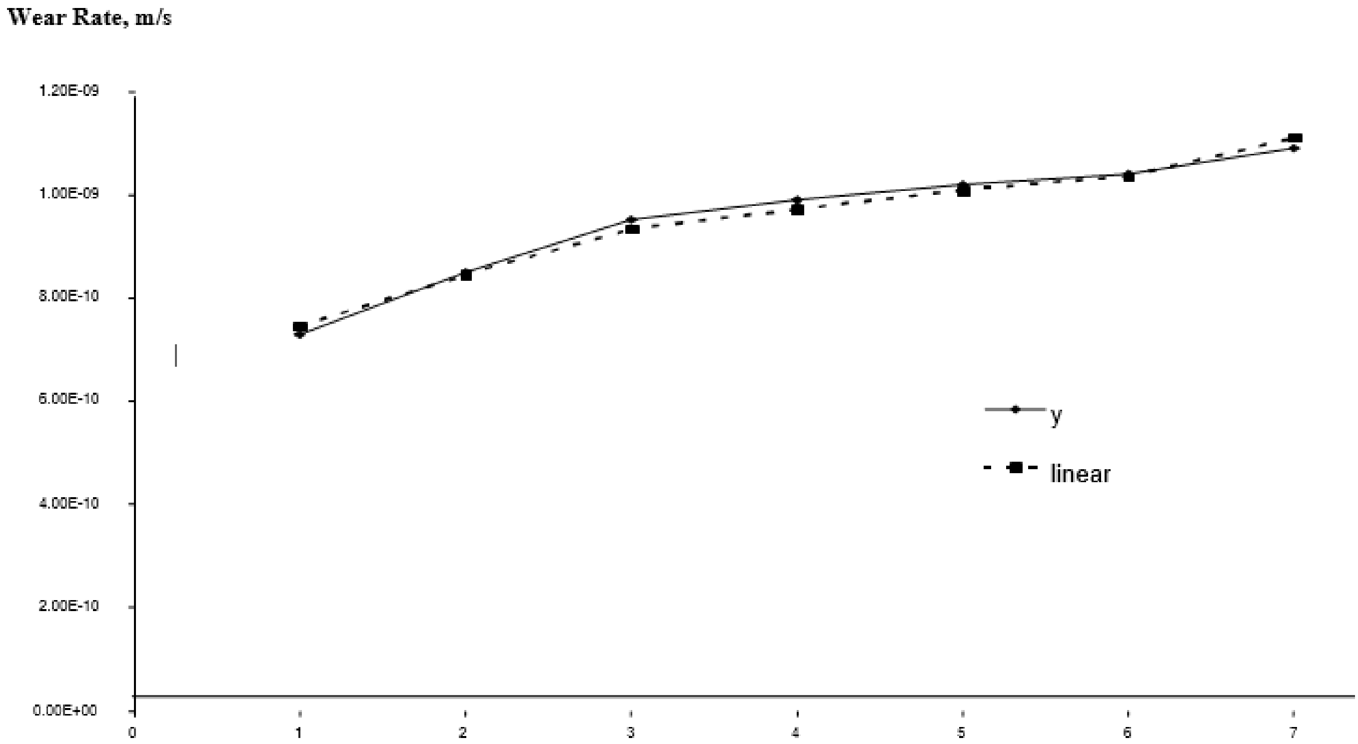

Fig. 3.0 Response curve for multiple linear model of N and Q

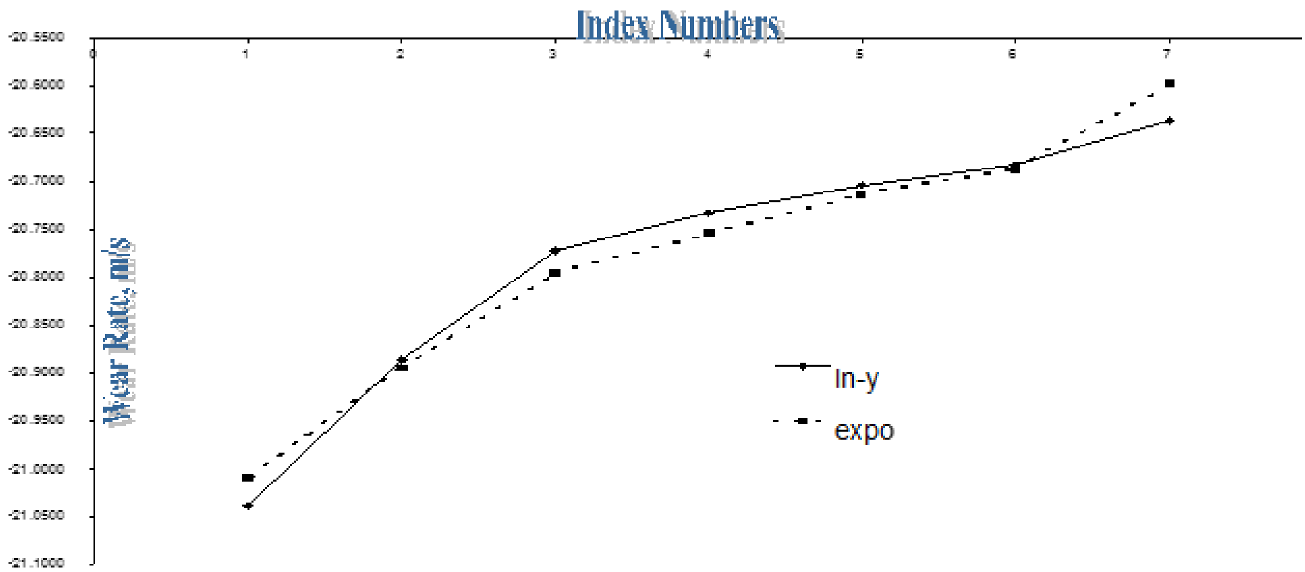

Fig. 4.0 Response curve for multiple exponential model of N and Q

5.3 Multiple Regression Double-Log Model of Press Speed and Throughput Capacity

A double-log model was also constructed to examine the wear behaviour of the flights under different values of the press speed and the throughput capacity. Table 3.0 shows the SAS printout of the model. The response curve is as shown in Fig.5.0. From the SAS printout, the equation for the model becomes;

$$\ln(Y) = -37.85916 + (1.99383)\ln(N) - (1.98366)\ln(Q) \quad (3)$$

Table 3.0 SAS printout for double log model of N and Q

The REG Procedure

Dependent Variable: ln_y ln_y

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	0.11540	0.05770	3618.78	<.0001
Error	4	0.00006378	0.00001594		
Corrected Total	6	0.11546			

Root MSE	0.00399	R-Square	0.9994
Dependent Mean	-20.77916	Adj R-Sq	0.9992
Coeff Var	-0.01922		

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	Intercept	1	-37.85916	1.76324	-21.47	<.0001
ln_n	ln_n	1	1.99383	0.16093	12.39	0.0002
ln_q	ln_q	1	-1.98366	0.22331	-8.88	0.0009

6. DISCUSSIONS

The primary goal of any regression analysis is to make a decision on whether to reject or accept the hypothesis. However, even with the best of decisions, some levels of error are bound to occur. Error occurs when a null hypothesis (hypothesis which we hope to disprove or reject) is rejected which is in fact true. The probability, α of committing this type of error is known as level of significant.

Thus, confidence interval = (1 - α)% , representing an interval of sample numbers within which reasonable conclusions about the population parameters can be drawn.

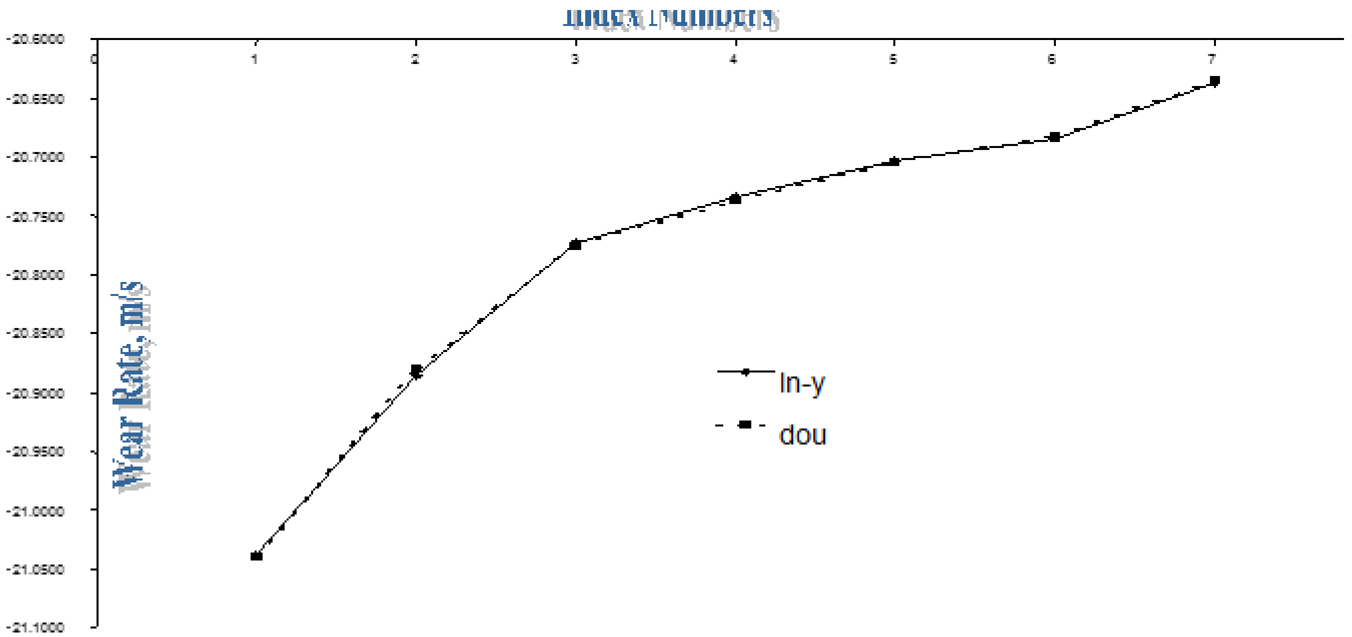

Fig. 5.0 Response curve for multiple double log model of N and Q

The rejection region is usually a set of computed values of the test statistics for which the null hypothesis is rejected. The value at the boundary of the rejection region is called the critical value. Critical values for relevant parameters will be defined as we proceed.

Table 4 shows the result of the multiple regression models. Choosing a 95% confidence interval or 0.05 significance level (Terry, 1982), the models can be analyzed as follows:

F – value of linear model is 131.69 with a significance probability of 0.0002, which is less than 0.05. Thus, the model is significant. This means that the combined effects of the press speed, N and the throughput capacity, Q on the wear rate of the flights is statistically significant. F-value of the exponential model is 64.02 with a significance probability of 0.009, which is also less than 0.05 and thus significant. The double-log model shows that the combined effects of N and Q on the wear rate is quite significant, having an F-value of 3618.78 with a significance probability of 0.0001.

Table 4.0: Regression Analysis Result

	LINEAR		EXPONENTIAL		DOUBLE-LOG	
Combined Effects of N and Q						
F-value /Probability	131.69 / 0.0002		64.02 / 0.009		3618.78 / 0.0001	
R-Square values	0.9850		0.9697		0.9994	
Individual Contributions of N and Q	**N**	**Q**	**N**	**Q**	**N**	**Q**
t-value / Probability	1.80 / 0.1466	-1.42 / 0.2276	1.41 / 0.2313	-1.15 / 0.3144	12.39 / 0.0002	-8.88 / 0.0009
Regression Coeffi-Cients	2.08893×10^{-10}	-1.22×10^{-6}	2.604×10^{-01}	-1564.323	1.99383	-1.98366

Generally, the R-square value shows the extent with which the estimated values approach the observed. A critical value of 0.75 or 75% is normally accepted.

R-Square value of the linear model is 0.9850. Thus, the model explains about 98% variations in the response curve. The model can, therefore be used for prediction purposes, having explained more than 75% variations in the response curve. The exponential model, with R-square value of 0.9697, explains about 96% variations in the response curve. Thus, the model can also be used for prediction purposes. The double-log model is even more suitable for prediction purposes, having explained about 99& variations in the response curve.

INDIVIDUAL CONTRIBUTIONS

The t-value gives a measure of marginal contributions by individual parameters. A critical probability of 0.20 is usually within safe limits (McClave, 1982). The t-value of N is 1.80 for the linear model, with a significance probability of 0.1466. This shows that the marginal influence of the press speed on the flights wear is quite significant. The marginal effect of throughput capacity, Q on wear appears insignificant with the model. This does not however, mean that Q has no effect on wear. The variation in Q can be occasional, with greater impact on wear. The exponential model shows that the marginal effects of N and Q on wear are significant. The double-log model shows that both N and Q have significant marginal effects on the wear rate, with significance probabilities of 0.0002 and 0.0009 respectively.

The Regression Coefficient of N and Q are 2.08893E –10 and –0.00000122 respectively for the linear model. This gives a positive relationship between the press speed and the wear rate, and a negative relationship with the throughput capacity. Precisely, one unit increase in press speed results in about 2.08893E –10 units increase in wear rate; also a unit increase in Q results in about 0.00000122 decrease in wear rate. This is obvious since the screw press has a specific design capacity, and Q was varied by adjusting the forward speed of the hydraulic cones. An increase in the hydraulic cone speed will ultimately increase the throughput capacity, with the press cake coming out at a faster rate. This will reduce the squeezing pressure which in turn will have a reducing effect on the wear of the flights. Much increase in Q will however, reduce the oil extraction efficiency of the system. The exponential model has regression coefficients of 0.26040 and –1564.32274 for N and Q respectively. This shows a positive relationship between the press speed and the wear rate, and a negative relationship with the throughput capacity. The double-log model has a regression coefficient of 1.99383 and –1.98366 for N and Q respectively, showing a positive relationship with the press speed, and a negative relationship with the throughput capacity and the wear rate of flights.

7. CONCLUSION

The multiple regression linear model takes into account about 98% of variations in the response curve. This is quite a promising result. It however tends to suppress the influence of the throughput capacity on the wear of the flights.

The exponential model explains about 96% of variations in the response curve. This is quite acceptable for prediction purposes. It however gives an unreliable result on the marginal contributions to the wear of the flights by both the press speed and the throughput capacity.

The double-log model explains about 99% of variations in the response curve, which is quite promising. It also gives a good account on the marginal contributions to the wear rate of the flights by the press speed and the throughput capacity.

Comparing the individual contributions to wear, the respective regression coefficients show that a slight change in the press speed or the throughput capacity gives a more sensitive response to wear under the double-log model. Thus, the double-log model is strongly recommended. The predicting model is thus:

$$\ln(Y) = -37.85916 + (1.99383)\ln(N) - (1.98366)\ln(Q) + \text{Random Error} \quad (4)$$

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