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Modeling of Metal Wear in Screw Presses in Palm Oil Mills

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Abstract: Four multiple regression models of press speed and throughput capacity were developed to examine the trend of wear in screw presses used in palm oil mills. A study by the author shows that the press unit constitutes point of severe wear in palm oil mills. Result shows that double-log model gave the best fitting curve for predicting the combined influences on the flights wear by the press speed and throughput capacity.

Key words: Wear, models, press screws, speed, flights, throughput capacity

INTRODUCTION

Wear life of power screws is difficult to predict due to too many influencing variables (Kragelsky, 1981). Such attempt would involve an understanding of the wear mechanisms, simple design and operational guidelines; the best result being that deduced from a life test performance. The screw press is generally a slow moving device. Dewatering is continuous and by gravity drainage at inlet end of press screw and by reducing the volume as material is being conveyed towards the discharge end. Proper screw design is critical (Hall, 1980), as different materials require different speeds, screw configurations, and screens for proper dewatering. The twin screw press found in modern oil mills is a continuous dewatering press that has proven successful in both virgin fibre and recycle mills.Unfortunately, the flights of the press screws undergo severe wear and breakdown.

MATERIALS AND METHODS

Measurements were made to generate data for the analysis. The press screw speed was varied by a variable speed pulley system. The throughput capacity was computed from timed samples of press cake and drained oil. Wear of flights was recorded over time and the wear rate calculated at different speeds and throughput capacities.

Simple regression models of press speed (n) and throughput capacity (q): Simple regression linear, quadratic and cubic models of press speed and throughput capacity, respectively have been developed to examine the individual influences to wear of the flights by these major factors. Result shows that quadratic models gave the best fitting curves (Okafor, 2006). Quadratic model equations for press speed and throughput capacity, respectively are:

$$Y = 5.88751E\text{-}11 + (1.04414E\text{-}10)\, N - (2.5377E\text{-}12)\, N'' + \text{Random error and}$$

$$Y = -5.0179E\text{-}10 + (9.874603E\text{-}7)\, Q - (0.00015041)\, Q^2 + \text{Random error}$$

where, Y is the wear rate of flights, N is the press speed and Q is the throughput capacity of the press

Multiple regression models of press speed and throughput capacity: Figure 1-4 show the linear, exponential, semi-log and double-log models of press speed and throughput capacity, respectively. Figure 5-8 give their respective computer printouts.

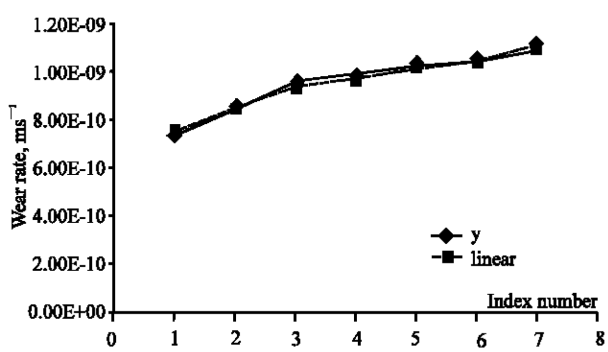

Fig. 1: Response curve for multiple Linear model of N and Q

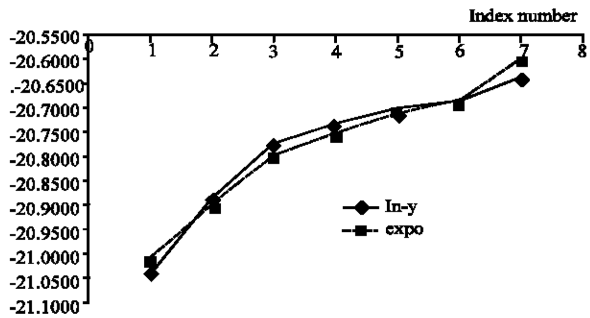

Fig. 2: Response curve for multiple exponential model of N and Q

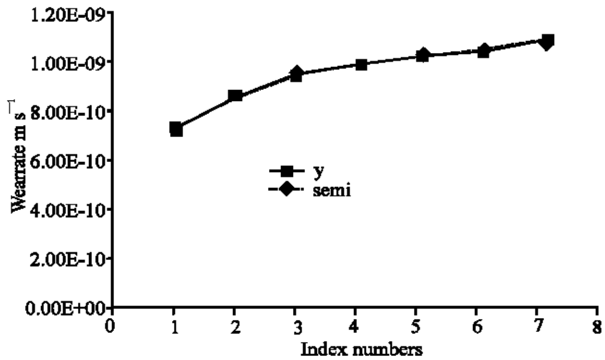

Fig. 3: Response curve for multiple semi-log model of N and Q

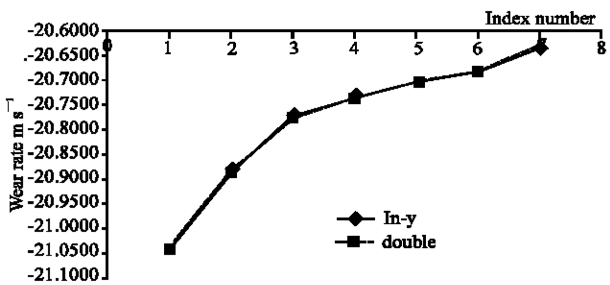

Fig. 4: Response curve for multiple double-log model of N and Q

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

Fig. 5: Computer printout for linear model of press speed and throughput capacity

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	0.11196	0.05598	64.02	0.0009
Error	4	0.00350	0.00087443		
Corrected total	6	0.11546			
Root MSE		0.02957	R-Square	0.9697	
Dependent mean		-20.77916	Adj R-Sq	0.9546	
Coeff var		-0.14231			

Parameter estimates

Variable	Label	DF	Parameter estimate	Standard error	T value	Pr>|t|
Intercept	Intercept	1	-20.46382	0.80326	-25.48	<.0001
n	n	1	0.26040	0.18467	1.41	0.2313
q	q	1	-1564.32274	1360.88352	-1.15	0.3144

Fig. 6: Computer printout for exponential model of press speed and throughput capacity

The REG procedure dependent variable: y y analysis of variance

Source	DF	Sum of squares	Mean square	F.value	Pr>F
Model	2	9.23997E-20	4.61998E-20	1367.11	<.0001
Error	4	1.35175E-22	3.37938E-23		
Corrected total	6	9.25349E-20			
Root MSE		5.81324E-12	R-Square	0.9985	
Dependent mean		9.53143E-10	Adj R-Sq	0.9978	
Coeff var		0.60990			

Parameter estimates

Variable	Label	DF	Parameter estimate	Standard error	t.value	Pr>|t|
Intercept	Intercept	1	-7.89472E-9	2.566995E-9	-3.08	0.0371
ln-n	ln-n	1	1.198751E-9	2.34284E-10	5.12	0.0069
ln-q	ln-q	1	-9.5929E-10	3.25109E-10	-2.95	0.0419

Fig. 7: Computer printout for semi-log model of press speed and throughput capacity

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

Fig. 8: Computer printout for double-log model of press speed and throughput capacity

RESULT AND DISCUSSION

The linear, exponential, semi-log and double-log model equations derived from the computer printouts are (Terry, 1982):

$Y = 1.123559E\text{-}9 + (2.08893E\text{-}10)N - (0.00000122)Q$,
$\ln(Y) = -20.46383 + (0.26040)N - (1564.32274)Q$,
$Y = -7.89472E\text{-}9 + (1.198751E\text{-}9)\ln(N) - (9.5929E\text{-}10)\ln(Q)$ and
$\ln(Y) = -37.85916 + (1.99383)\ln(N) - (1.98366)\ln(Q)$,
respectively.

At 95% confidence interval or 0.05 significance level (Mendenhall, 1981);

F-Values are 131.69, 64.02, 1387.11 and 3618.78 with significance probabilities of 0.0002, 0.009, 0.0001 and 0.0001 for the linear, exponential, semi-log and double-log models, respectively. This shows that the models have different levels of significant. That is, the combined effects of press speed and throughput capacity on wear is statistically significant. The semi-log and double-log models, each with significance probability of 0.0001 give more significant results.

R-Square Values for the models are 0.9850, 0.9697, 0.9985 and 0.9994, respectively. Thus, any of the models can be used for prediction purposes, having explained more than 75% variations in their response curves. The semi-log and double-log models with R-Square values of 0.9985 and 0.9994 gave the best fitting curves.

Individual contributions: T-Values for N are 1.80,1.41, 5.12 and 12.39 with significance probabilities of 0.1466, 0.2313, 0.0069 and 0.0002 for the models, respectively. Except the exponential model, the remaining models gave significant marginal effect of press speed on wear. The double-log model gave the greatest marginal effect with a t-value of 0.0002.t-Values for Q are-1.42,-1.15,-2.95 and-8.88 with significance probabilities of 0.2276, 0.3144, 0.0419 and 0.0009 for the models, respectively. Thus, the marginal effect of throughput capacity on wear is significant for the semi-log and double-log models, and appears insignificant for linear and exponential models. The result of the latter does not however mean that throughput capacity has no effect on wear.

Regression Coefficients of N are 2.08893E-10, 0.26040, 1.198751E-9 and 1.99383 for the models, respectively. This gives a positive relationship between the press speed and wear rate of flights. That is, the wear rate increases with increase in press speed. Considering the linear model for instance, one unit increase in press speed results in 2.08893E-10 units increase in wear.

Regression Coefficients of Q are -0.00000122, -1564.32274, -9.5929E-10 and -1.98366 for the models, respectively. This gives a negative relationship between the throughput capacity and wear (McClave, 1982). That is, wear rate decreases with increase in throughput capacity. This is understandable since the screw press is normally designed for specific capacity. Throughput capacity was varied by adjusting forward speed of the hydraulic cones. An increase in hydraulic cone speed increases throughput capacity since the press cake will now come out at a greater rate. This consequently decreases the squeezing pressure which invariably has a reducing effect on the wear rate of flights. Much increase in throughput capacity will however reduce the palm oil extraction efficiency of the press.

RECOMMENDATION

The double-log model gave the best fitting curve for predicting wear of flights in the system. Thus, the recommended model is:

$$\text{Ln } Y = -37.85916 + (1.99383)\ln N - (1.98366)\ln Q + \text{Random error}$$

The random error term takes care of contributions to wear of the flights by minor variables.

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