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Minimizing Metal Wear in Screw Presses in Palm Oil Mills

Basil Okafor
Department of Mechanical Engineering,
Federal University of Technology, Owerri-Imo State, Nigeria

Abstract: Metal wear has been identified as the main problem facing screw presses used in palm oil mills. The flights of the press screws experience severe wear. In a related research by the author (reported elsewhere), a multiple regression double-log model was developed to predict wear in press screws used in palm oil mills. The model served as best fitting curve for predicting wear in the system. Using the model, optimal operating conditions of press speed and throughput capacity has been established. Wear of flights is reduced to minimum at optimal press speed of 8 rev min^{-1} and 2.8485 E-10 m^3/s throughput capacity.

Key words: Model, throughput capacity, press speed, minimum wear, flights

INTRODUCTION

Wear results whenever there is relative motion between moving parts of a machine. The rate at which material is removed depends on many variables. this makes generalization difficult, even in apparently simple cases (Stolarski, 1999). Wear life of power screws is thus difficult to predict. However, once the major influencing variables are specified, a reasonable result can be achieved. A general knowledge of the wear mechanism, some simple design and operating guidelines as well as resorting to life testing will help to get the best result (Kragelsky, 1981).

The prediction models: Figure 1 and 2 show quadratic models which gave best fitting curves for predicting the individual influences on wear in press screw flights by press speed, N and throughput capacity, Q. Figure 3 also shows the double-log model which gave the best fitting curve for predicting the combined influences of press speed and throughput capacity on wear of flights (Okafor, 2007).

Maximum values of press speed (N) and throughput capacity (Q): From the quadratic model of press speed; Y = 5.88751E-11 + (1.04414E-10) N – (2.5377E-12) N”
Y = $⇂_0$ + $⇂_1$N - $⇂_2$ N”; where ⇂o, ⇂1 and ⇂2 are constants; ∂Y/∂N =⇂1 - 2⇂2 N; ∂”Y/ ∂N” = - 2⇂2⇒ max.
Thus to maximize N; ∂Y/∂N = 0 = ⇂1-2⇂2 N; N =⇂1/2⇂2=1.04414E-10 / 2×2.5377E-12 =20 rev/min max

From the quadratic model of throughput capacity; Y =-5.0179E-10 + (9.874603E-7) Q - (0.00015041) Q”
I e.,Y= ⇂o+⇂1Q-⇂2 Q”; ∂Y/∂Q = ⇂1-2⇂2 Q; ∂”Y / ∂ Q” = -2⇂2 ⇒ max (Kreyszig, 1985).

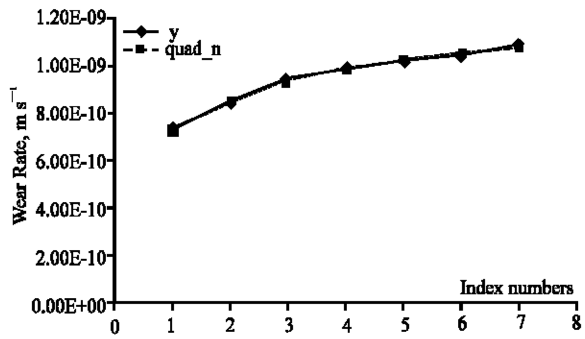

Fig. 1: Response curve for quadratic model of N; Y = 5.88751E-11 + (1.04414-10) N– (2.5377E-12)$N^{2”}$

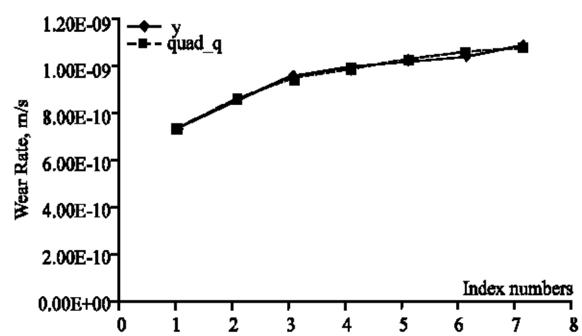

Fig. 2: Response curve for quadratic model of Q; Y = +5.88751E-11 + (1.04414-10) Q– (2.5377E-12)$Q^{2”}$

To maximize Q; ∂Y/∂ Q = 0 =⇂1-2⇂2Q ; Q =⇂1/ 2⇂2 = 9.874603E-7/(2×0.00015041) =3.28×10-≥m≥/s.

MINIMIZING PRESS SPEED, N

From the double-log model for predicting the combined influences of press speed, N and throughput capacity, Q on wear of press screw flights, value of press speed to give a minimal influence on wear is determined as follows: lnY = -37.85916 + (1.99383) ln N-(1.98366) lnQ; where Y is wear rate of flight.

Hence ln Y = $\downarrow_o$ + $\downarrow_1$ ln N - $\downarrow_2$ ln Q; where $\downarrow_o$, $\downarrow_1$ and $\downarrow_2$ are constants

Y = EXP (↓o + $\downarrow_1$ ln N - $\downarrow_2$ ln Q);Let u = $\downarrow_1$ ln N ;∂u/∂N = $\downarrow_1$ / N

Then Y = EXP (↓o + u - $\downarrow_2$ ln Q); Y = EXP ($\downarrow_o$). EXP (u). EXP (- $\downarrow_2$ ln Q)

∂Y / ∂u = EXP ($\downarrow_o$). EXP (u);∴ ∂Y/∂N = (∂Y/∂u)(∂u/∂N) = EXP ($\downarrow_o$). EXP (u). $\downarrow_1$ / N

∂Y/∂N= $\downarrow_1$/N EXP (↓o). EXP ($\downarrow_1$ ln N)= $\downarrow_1$/N EXP (↓o). EXP ($\downarrow_1$ ln N)

Test for minimum: From∂Y/∂N = $\downarrow_1$/N EXP (↓o). EXP ($\downarrow_1$lnN); let u = $\downarrow_1$ ln N, hence ∂u/∂N = $\downarrow_1$ / N

Then∂Y/∂N = $\downarrow_1$/N EXP (↓o). EXP (u); ∂/∂u (∂Y/∂N) = $\downarrow_1$/N EXP (↓o). EXP (u)

∴ ∂"Y/∂N" = ∂/∂u (∂Y/∂N). ∂u/∂N = $\downarrow_1$/N EXP ($\downarrow_0$). EXP (u). $\downarrow_1$/N

∂"Y/∂N" = $\downarrow_1$"/N" EXP ($\downarrow_0$). EXP ($\downarrow_1$ ln N) ⇒ minimum (positive) (Keith, 1982).

Thus, for minimum value of N; ∂Y/∂N = $\downarrow_1$/N EXP ($\downarrow_0$). EXP ($\downarrow_1$ ln N) = 0

But $\downarrow_1$/N ± 0,henceEXP ($\downarrow_0$). EXP ($\downarrow_1$ ln N) = 0

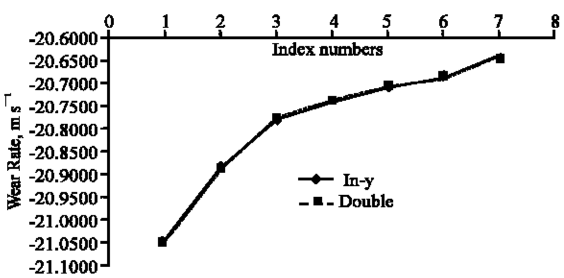

Fig. 3: Response curve for double-log model of N and Q; Lny= -37.85916 + (1.99383) lnN - (1.98366) lnQ

Taking anti-natural logarithm on both sides; $\downarrow_0$ EXP (2.71828). $\downarrow_1$ ln N EXP (2.71828) = 1

15.154 (↓o)×15.154 (↓1 ln N) = 1; ↓o. ↓1 ln N = 0.0043545

ln(N) = 0.0043545/↓o.↓1 = 0.0043545/(-37.85916)(1.99383) = -0.000058;

hence ln(N) = -0.000058 ; N = EXP (-0.000058) = 1 rev min^{-1} minimum.

The above minimum value of press speed is obviously not practically feasible. The derived maximum and minimum values however give a range of values within which values of press speed can be manipulated.

Considering a 70% reduction in wear rate of the flights; Design data for the twin screw press taken as a case study: Press Speed, N is12 rev/min. and Throughput Capacity, Q is 2.21×10-3 m≥/s

From the double–log model; ln(Y) = -37.85916 + (1.99383) ln N - (1.98366) ln Q

ln(Y) = -37.85916 + (1.99383) ln(12) – (1.98366) ln(2.21×10-≥; hence Y = EXP (-20.775) = 9.495×10^{-10}

For 70% reduction in wear rate; Y = 9.495×10^{-10}-($9.495\times10^{-10}\times0.70$) = 2.84839×10^{-10} m s^{-1}.

Using an operational press speed of 10 rev/min. (which is practically convenient and also within the minimum ~ maximum range of values of N); from the double–log model;

ln (2.84839 × 10-≠° m s^{-1}) = -37.85916 + (1.99383) ln(10) – (1.98366) lnQ

i.e., -21.9791 = -37.85916 + 4.59096 - (1.98366) lnQ

ln Q = (-37.85916 + 4.59096 + 21.9791) / 1.98366 = -5.6910;

Q = EXP (-5.6910) = 3.376×10-≥ m≥/s

The above value of Q is greater than the maximum feasible throughput capacity value of 3.28×10^{-3} m≥ s^{-1}. Thus, it is not possible to reduce wear rate of flights by 70% under the above operating conditions.

There are two possible options; either to reduce:

- Operational speed of the press, or
- Percentage reduction in wear rate

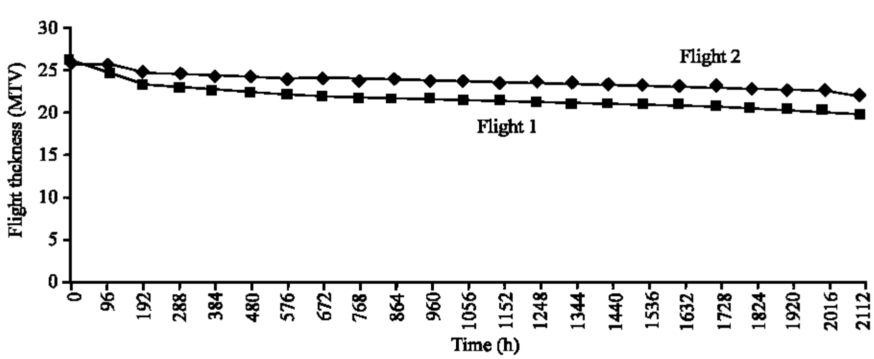

Fig. 4: Functional wear rate of flights

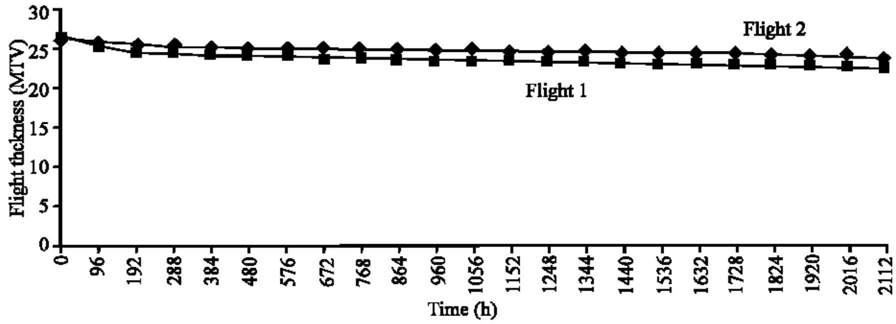

Fig. 5: Reduced wear rate of flights

Choosing a press speed of 8 rev min^{-1} and with 70% reduction in wear rate of flights;
$Y = 9.495\times10^{-10} - (9.495\times10^{-10}\times0.70) = 2.8485\times10^{-10}$ ms^{-1};
Thus, from the double–log model:
ln (2.8485×10-≠°) = -37.85916 + (1.99383) ln(8) – (1.98366) ln Q
i.e., -21.979 = -37.85916 + 4.146 – (1.98366) ln Q
ln Q = (-37.85916 + 4.146 + 21.979) / 1.98366 = -5.91538; Q = EXP (-5.91538) = 2.6976×10-≥ m≥/s.

The above value is less than the maximum feasible throughput capacity value of 3.28×10-≥ m≥/s. Thus, a 70% reduction in wear rate of flights is practically feasible. This means that under the above operating conditions, the flights will assume a wear rate of 2.8485×10^{-10} ms^{-1} (2.8485E-7 mm s^{-1}) after initial wear-in.

Figure 4 shows the wear behaviour of the flights and Fig. 5 shows the reduced wear rate of 3.19032×10^{-10} m s^{-1} for the flights, giving about 70% reduction in the wear rate of the flights.

CONCLUSION

Operating the press at an optimal condition of 8 rev min^{-1} and throughput capacity of 2.6976×10-≥ m≥/s will drastically reduce wear in the system. It is however noted that the above result is not a general case. To achieve the best result, each case must be specifically analyzed based on the prevailing operating conditions.

Then, the above approach can be applied in all cases. It is also worthy to note that increasing the throughput capacity is likely to affect the palm oil extraction efficiency of the system. Thus, a compromise optimal condition must be sort for each particular case.

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