Energy Losses in a Ram Press Machine for Vegetable Oil Expression

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1. Introduction

The ram press machine analyzed in this paper was originally invented by Carl Bielenberg at Appropriate Technology International [1]. During last decades ram press machines have been manufactured in thousands of replicates, successfully sold, and continuously used across the African continent. A simplified mechanical model of the ram press machine was already proposed and analysed [2]. It considered the effect of the offset ratio and the ram press proportions on the mechanical advantage (MA), efficiency and the velocity ratio (VR) in terms of the angle of rotation of the lever (handle).

The objective of this study is to evaluate the energy losses associated with the friction in the sliding bearings and the piston-cylinder pair of CAPU 40 ram press machine.

2. Materials and Methods

For the purposes of the study a new mechanical model of the machine was proposed, equations governing the equilibrium of the piston and the lever were derived and analysed. A unique pressure measuring device was designed, manufactured and used to measure the pressure variation on the face of the piston during the working cycle. The results obtained were used to compare the energy input and energy output for three values of the coefficient of friction and an energy balance in the machine was made. Figure 1 shows the free-body diagram of the ram press components and the corresponding forces and torques acting upon them, where R is the load on the face of the piston (3), N_1 and N_2 are the normal reactions on the piston, F is the total friction force acting on the piston, T is the tension force on the connecting rods (2), D is the resultant reaction on the bearing D of the lever (1). On the other hand angle δ specifies the line of action of the reaction D, and $M_B = \mu rT$, $M_D = \mu rD$ and $M_E = \mu rT$ are the friction torques on bearings B, D and E respectively. Also E is the effort applied by the operator on the lever (1) applied at right angles to it.

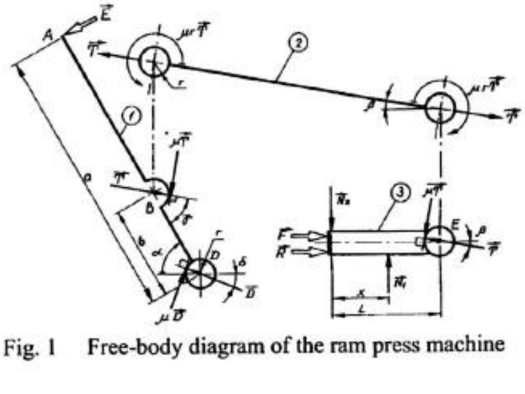

Fig. 1 Free-body diagram of the ram press machine

Since the machine operates at very low speed the dynamic effects were neglected and the equilibrium of the ram press machine components was considered.

The equations of equilibrium of the piston are:

$$R + F_3 + \mu(N_1 + N_2) - T(\cos\beta + \mu\sin\beta) = 0, \tag{1}$$

$$N_1 - N_2 + T(\sin\beta - \mu\cos\beta) = 0, \tag{2}$$

$$\mu rT - N_1\left(l - x - \mu\frac{d}{2}\right) + N_2\left(l - \mu\frac{d}{2}\right) = 0, \tag{3}$$

where μ - the coefficient of friction assumed to be the same for all contact surfaces, T- the tension force on the connecting rod, d- the piston diameter, r- the radius of all bearings, and $\sin\beta = \frac{b}{c}\sin\alpha$.

Expressions for the unknown forces T, N_1 and N_2 were found by solving (1), (2), and (3):

$$T = \frac{(R+F_3)x}{\mu[2\mu r + (\sin\beta - \mu\cos\beta)(2l - \mu d - x)] + x(\cos\beta + \mu\sin\beta)} \tag{4}$$

$$N_1 = \frac{-(R+F_3)\left[\mu r + (\sin\beta - \mu\cos\beta)\left(l - \mu\frac{d}{2}\right)\right]}{\mu[2\mu r + (\sin\beta - \mu\cos\beta)(2l - \mu d - x)] + x(\cos\beta + \mu\sin\beta)} \tag{5}$$

$$N_2 = \frac{-(R+F_3)\left[\mu r + (\sin\beta - \mu\cos\beta)\left(l - x - \mu\frac{d}{2}\right)\right]}{\mu[2\mu r + (\sin\beta - \mu\cos\beta)(2l - \mu d - x)] + x(\cos\beta + \mu\sin\beta)} \tag{6}$$

The equations of equilibrium of the lever are:

$$D_x - T\cos\beta + E\sin\alpha = 0, \tag{7}$$

$$D_y - T\sin\beta - E\cos\alpha = 0, \tag{8}$$

$$Ea - T(\mu r + b\sin\gamma) - \mu rD = 0. \tag{9}$$

where: D_x and D_y are the components of the total reaction acting on the bearing D, and $\gamma = (\alpha - \beta)$.

Effort E and the reaction D:

$$E = \frac{\mu rD + TA}{a}, \tag{10}$$

$$D = T\frac{\cos\beta - \mu\sin\beta - \frac{A}{a}\sin\alpha}{\cos\delta - \mu\sin\delta + \frac{\mu r}{a}\sin\alpha}, \qquad (11)$$

where, $A = b\sin\gamma - \mu(b\sin\gamma - r)$.

In addition to that angle δ is determined from the equation

$$\left(B^2 + C^2\right)\sin^2\delta - 2BD\sin\delta + D^2 - C^2 = 0 \qquad (12)$$

where,

$$B = \left(1 + \mu^2\right)\cos\beta + \frac{A}{a}(\mu\cos\alpha - \sin\alpha), \qquad (13)$$

$$C = \left(1 + \mu^2\right)\sin\beta + \frac{A}{a}(\cos\alpha + \mu\sin\alpha), \qquad (14)$$

$$D = \cos(\alpha - \beta) + \mu\sin(\alpha - \beta). \qquad (15)$$

By using a specially designed pressure measuring device the variable pressure acting upon the face of the piston during the working cycle was determined. The pressure was read for eight consecutive values of angle α and each experiment was repeated 5 times. A soft shell sunflower seed (Mopane variety) was pressed and sunflower oil expressed under real conditions. Then the mean pressure *P(α)* was used to calculate forces acting on the piston such as *R*, N_3, and $F_3 = \mu^* N_3$ and the unknown forces *T*, N_1, N_2, *D*, *E*, and $F = \mu N_1 + \mu N_2 + \mu^* N_3$ were calculated for the same values of angle α.

3. Estimating the Energy Losses

The results obtained for the forces were used to plot the some graphs for μ = *0.2*, *0.3*, and *0.4*. These graphs are: Effort *E* vs. tangential displacement of handle, *E = f(TDH)*, Work load *R* vs. cumulative piston displacement, *R= f(CPD)*, Friction torque on bearing *B* vs. angle γ, $M_B = f(\gamma)$, Friction torque on bearing *D* vs. angle α, $M_D = f(\alpha)$, Friction torque on bearing *E* vs. angle β, $M_E = f(\beta)$, and the Total friction force *F* vs. cumulative piston displacement, *F= f(CPD)*. By numerical integration of the areas under the above graphs the energy input, energy output, and energy losses in the ram press system were determined and the estimated results are listed in Table 1.

To visualize the energy losses in the ram press the graphs shown in Fig. 2 were plotted. They present that the highest energy losses are generated at the piston-cylinder pair followed by the losses in the bearings *D* and *B*. The energy losses in bearing *E* are much smaller than the rest because of the smaller angle of rotation β, although that force *T* acting upon *B* and *E* is the same. From Table 1 it can be seen the input and output energies are almost the same. This indicates that the energy analysis was correct and conducted with reasonable accuracy of the calculations.

Table 1 Energy losses in the ram press machine

Energy [j/cycle]	µ	0.2	0.3	0.4
Energy input- E_i	$E_i = E_i(TDH)$	1022.6	1219.7	1510.4
Energy losses- E_L	$M_B = f(\Delta\gamma)$	98.1	158.8	239.0
	$M_D = f(\Delta\alpha)$	108.7	175.8	264.4
	$M_E = f(\Delta\beta)$	11.7	19.0	28.5
	$W_F = f(CPD)$	152.1	221.0	342.5
Energy output- E_o	$R = f(CPD)$	663.6	663.6	663.6
Energy balance	$\Sigma\,(E_o + E_L)$	1034.3	1238.2	1538.0
Difference in %	$\frac{E_i - (E_o + E_L)}{E_i}$	1.14	1.52	1.83

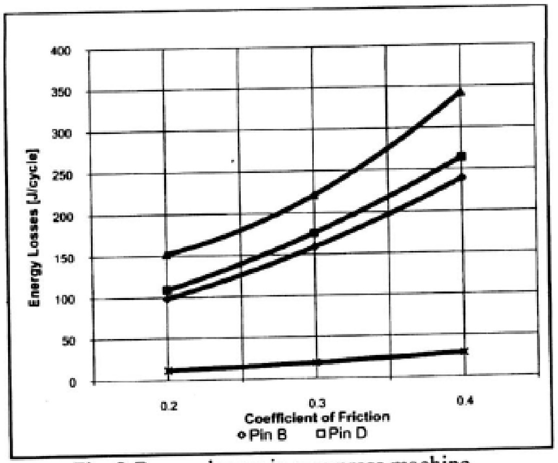

Fig. 2 Energy losses in ram press machine

4. Conclusions

Based on the above analysis the following conclusions were drawn:

- The major energy losses were found to be in the piston-cylinder pair and bearings *D* and *B*.
- The energy losses in bearing *E* were found to be negligibly small than the others.
- Energy balance varies between 1.14 and 1.83 %.

5. References

[1] ATI, 1985. Appropriate Technology International (ATI) and Lutheran World Relief (LWR), Tanzania.

[2] Uziak J., Loukanov I.A., Foster J.D.G., 2002 - A Simplified Model of an Offset Ram Press for Sunflower Oil Expression. *African Journal of Science and Technology*, Vol. 3, No. 1, pp. 61-69.