CASE STUDY

Measurement of Operating Forces in a Ram Press Crushing Sunflower Seed

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ABSTRACT: This study presents the experimental setup and results of measurement of forces and moments in a manually operated ram press machine. Tests were conducted on a BP30 ram press using electrical resistance strain gauges to measure forces present in the machine under operating conditions. The forces were obtained by capturing data for the strains in six channels, using a digital instrument system, and later calculated by using the sensitivity factors. A method was proposed to estimate the tension force and bending moment in the connecting rods based on the sums and differences of measured strains. Results obtained were converted into spreadsheet data and presented in graphs versus the position angle of the operating lever.

KEY WORDS: *digital transducer, micro-strains, ram press, sensitivity factors, strain gauges*

Introduction

The manually operated press for seed oil extraction known as the ram press is a machine originally developed by the Appropriate Technology International (ATI) [1] for use with edible oilseeds such as sunflower and groundnut. The original machine and later models are widely used in rural areas of many African countries [2]. Studies have analysed the mechanical operation of its design and were previously able to measure experimentally the variation of expression force applied to the seed cake by the piston [3–5]. Knowledge of force levels in the mechanism is useful in order to determine improvements that will enhance the energy efficiency of the machine. This study effectively extends the previous studies by experimental measurement of several other selected forces in the machine.

Physical Arrangement

The data of the experiment were collected by pressing sunflower seed with a ram press BP30, representing the commonest application of the machine in recent years. Figures 1 and 2 show the essential components of the ram press slider–crank mechanism and the location of the strain gauges employed in the experimental study.

The strain gauges are attached at different locations such as:

- at the piston near its journal, arranged in a four-gauge bridge;
- at the upper and lower edges of each of the two rectangular bars that form the connecting rod pair wired as separate active gauges, each having its own dummy gauge so as to obtain four separate data channels;
- at the operating lever which forms the crank of the slider–crank mechanism arranged in a two-gauge bridge.

A signal representing the position of the mechanism was derived from an angle-of-rotation digital transducer that was mounted coaxially with the fixed pivot axis of the operating lever. The signal obtained from the digital transducer establishes simultaneous recording of the crank angle of the mechanism, permitting the forces and moments to be related to the position of the mechanism.

Instrument System

Signals from the transducers were polled in a cycle of nine data channels. In addition to the seven channels described above for force and position sensing, two channels were employed for eliciting: (a) synchronisation signal, and (b) temperature data from a thermocouple.

The sample interval for the TML data logger was determined by the software (TML 7300E, Tokyo Sokki

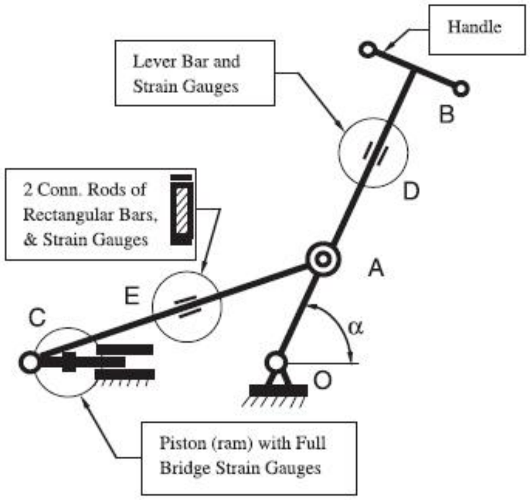

Figure 1: Schematic diagram of ram press

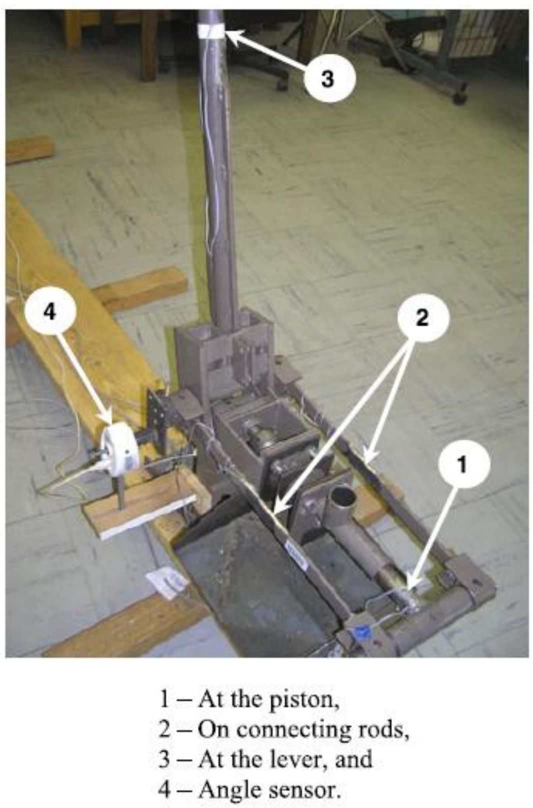

Figure 2: General arrangement of sensors: 1 – at the piston; 2 – on connecting rods; 3 – at the lever; and 4 – angle sensor

Kenkyujo Co. Ltd., Tokyo, Japan) running on the desktop computer, which limited the capture speed to one data cycle per second. Temperature data were recorded for the purpose of analysing any variation that might appear in machine performance. In some seasons the working temperature may change up to 25°C during the course of a day. However, during the tests there was no signification variation in temperature. Captured data were transferred to spreadsheet format, in order to combine and align the two stored data files, and to convert the rotation signal to angle and the micro-strain figures to force and moment units.

Table 1: Sensitivities $\mathbf{k}_i$ of measured strains to applied forces

Sensitivity and units	Channel no.	Measured values of $\mathbf{k}_i$	Values of $\mathbf{k}_i$ from material constants
Piston compressive force $\mathbf{k}_1$ ($\mu\varepsilon$/kN)	1	6.64	7.1
Handle force $\mathbf{k}_2$ ($\mu\varepsilon$/N)	2	0.956	0.953
Bar tension $\mathbf{k}_3$ ($\mu\varepsilon$/kN)	3	27.3	27.8
Bar tension $\mathbf{k}_4$ ($\mu\varepsilon$/kN)	4	27.3	27.8
Bar tension $\mathbf{k}_5$ ($\mu\varepsilon$/kN)	5	24.4	27.8
Bar tension $\mathbf{k}_6$ ($\mu\varepsilon$/kN)	6	*	27.8

*Channel 6 data were discarded.

Calibration of the Force Sensors

The sensitivities of the measured strains to the levels of force or moment in the mechanism were measured by separate calibrations, after the completion of the sunflower pressing tests. The results are given in Table 1. The piston was mounted over a load cell of known accuracy in a fixture that applied an axial compressive force from a tensile/compressive material testing machine. The second channel of data, from the two-active gauge bridge sensing the bending strain in the operating lever, were calibrated with the lever in a horizontal position using standard weights applied to the handle. Channels 3 to 6, which sense tensile strain in the pair of rectangular bars forming the connecting rod, were calibrated on a separate tensile test machine, using its built-in load cell. Note that the total force in the connecting rod pair is the sum of the separate forces in each of the connecting rods. Sensitivities were the slopes of the best-fit lines over the range of measurements. All calibration curves were found to be linear with small scatter. The last column of Table 1 shows the estimated sensitivities based on simple geometry and commonly used values for the elastic modulus and Poisson's ratio.

Determination of Friction Couple at Crank-to-Connecting Rod Link

The factors that have to be used to calculate the force values for the piston compressive force (at point 1 in

Figure 2) and the handle force (at B in Figure 1) follow simply from Table 1. However, the tensile forces and the moments in the connecting rods (at E in Figure 1) require the sum and difference respectively of a pair of strains. The analysis below shows how the tensile force, as well as the bending moment caused by the friction couple acting at the end link was derived.

Consider a rectangular flat bar carrying tensile force F and bending moment M. Let the section depth be d and the width be b. Moreover, let E represent Young's modulus. Let the section area be $A = bd$ and section second moment of area $I = bd^3/12$. Designate the top edge as A and the bottom edge as B (the strain gauges are mounted on these edges).

During calibration, when there was no bending moment,

$$\varepsilon = kF$$

where k is the measured sensitivity in suitable units while

$$\varepsilon = \frac{\sigma}{E} = \frac{F}{AE},$$

so the effective value of AE is given by the experimental measurement of k as

$$AE = \frac{1}{k} \tag{1}$$

The combined stresses at edges A and B are given by the equation pair:

$$\sigma_A = \frac{F}{A} + \frac{Md}{2I} \tag{2}$$

$$\sigma_B = \frac{F}{A} - \frac{Md}{2I} \tag{3}$$

Combining Equations (1), (2) and (3) with the expressions for A and I in terms of b and d, gives

$$F = \frac{\varepsilon_A + \varepsilon_B}{2k} \tag{4}$$

$$M = \frac{d(\varepsilon_A - \varepsilon_B)}{12k} \tag{5}$$

Typical Result Patterns

The maximum compressive force under the conditions of the experimental study was approximately

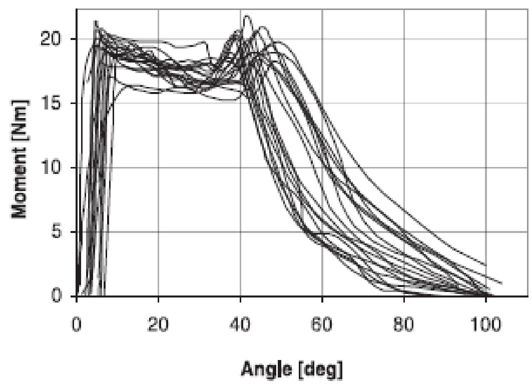

Figure 3: Variation of bending moment

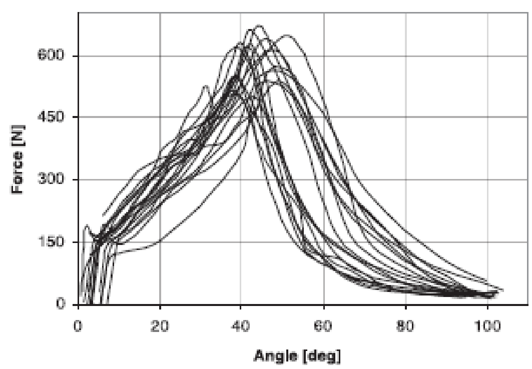

Figure 4: Variation of force on the lever

12 kN. Graphs of the piston force (channel 1) against crank rotation had a characteristic shape that was also displayed by graphs (Figure 3) showing connecting rod-bending moment (from channels 3 to 6).

Figure 4 shows the variation of the tangential component of the handle force (at B in Figure 1), obtained from the channel 2 readings. This force had a sharp peak during the operating cycle, reaching up to 650 N. By knowing the bending moment, which corresponds to the friction couple in the sliding bearing and the radius of the same journal, one can estimate the coefficient of friction and the energy losses at the bearing.

Based on the above results of the experimental study another study will examine the energy expended in the various joints of the machine and the implications for improving the design, the efficiency and the ease of use.

Conclusions

The paper has described a method for experimental measurements of forces and moments in the manually operated BP30 ram press. Curves showing some of the variable forces and moments that were measured in the tests have been used to present the results. The results described in this paper will be used separately to examine the energy balance in the ram press machine and to estimate the actual values of the coefficient of friction in the bearings.

References

1. ATI. (1989) *Proceedings of the Meeting: Oilseeds and the Bielenberg Ram Press*, Nairobi, Kenya. Appropriate Technology International (ATI), Washington, DC.
2. Zulberti, C., Schmidt, O. and Mugeto, J. (1990) *Dissemination of the Ram Press*. Proc. of the Bielenberg Ram Press and Small-Scale Oil Processing, Nairobi, Kenya. Appropriate Technology International (ATI), Washington, DC.
3. Loukanov, I. and Uziak, J. (2002) Theoretical and experimental analysis of forces and energy utilization in a ram press machine for sunflower oil expression. *Mech. Machines,* **41**, 24–31.
4. Uziak, J., Loukanov, I. A. and Foster, J. D. G. (2002) A simplified model of an offset ram press for sunflower oil expression. *Afr. J. Sci. Technol. (AJST), Sci. Eng. Ser.*, **3**, No. 1, 61–69.
5. Loukanov, I. A. and Uziak, J. (2001) *Theoretical Analysis of an Offset Single Stroke Ram Press for Sunflower Oil Extraction,* vol. 1. Proc. Eighth IFToMM Int. Symp. Theory Machines Mechanisms SYROM 2001, Bucharest, Romania, 165–170.