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MEASUREMENT OF FORCE INVOLVED IN COMPRESSION OF LINT COTTON ON A MECHANICAL BALING PRESS

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Abstract: *Cost of processing of lint cotton is very high. In order to optimize this, designing a mechanical press for compressing lint cotton does decentralization of ginnery. This design is carried out after performing extensive experiments on waste cotton pressing machine. During this experimentation it is required to measure the various variables involved in the process. The work presented in this paper reports the experiments carried out and the method used to measure force required for compressing cotton using mechanical press.*

Key words*: Cotton, Compressive force, Electro Mechanical system, Shock load.*

1. INTRODUCTION

Cotton from time immemorial has held the highest place amongst the family of fibers-natural or man made. Ginning is the separation of fiber (lint cotton) from cottonseed. Lint cotton then compressed in the form of a bale weighing 170-220kg having density of 580-640 kg per cubic meter. The existing press machine used for compressing lint cotton has many drawbacks. Therefore a screw type mechanical medium duty press machine is designed (Agrawal et al., 2003) after carrying out extensive research & experimentation on mechanical press machine, used for compressing waste lint cotton.

2. PROCEDURE OF EXPERIMENTATION

Experimentation planning was made to conduct experimentation on screw type bale making machine which involved the following steps (Schenck, 1961).

- Identification of Variables.
- Dimensional Analysis
- Test Planning..
- Selection and Calibration of Instruments.
- Test Data Checking and Rejection.
- Data analysis

2.1 Identification of Variables

There are various independent and dependent variables involved during the experimentation. The Independent Process Variables (Anthony & McCaskill , 1977) are Length of box-L, Width of box-B, Moisture content in lint cotton-M, Weight of lint cotton-W, Speed of screw-V, Total moment of inertia- of mechanical power transmission system-I, and Instantaneous time during compression-t. The dependent variables are Force of compression-F, Energy of compression- E, Density of compressed bale- ρ, Displacement of platen- S and Total time of compression- T. Similarly there are some extraneous variables which are difficult to control like climatic condition, manpower limitations, error in kinematics travel of platen, error of instrumentation etc.

A major step in the performance of the experiment is the measurement of the output parameter especially the force. The objective of the proposed paper is to establish appropriate measurement techniques for the measurement of the compressive force required to compress the lint cotton by using mechanical press.

2.2 Dimensional Analysis

The dimensionless equations for dependent variables obtained by dimensional analysis are

$$\mathbf{F/W} = K[\,(B/L)^b, M^c, (g,L/V^2)^f, (V^2 I / L^3 W)^g, (tV/L)^h\,] \quad (1)$$

$$\mathbf{E/LW} = K[\,(B/L)^b, M^c, (g,L/V^2)^f, (V^2 I / L^3 W)^g, (tV/L)^h\,] \quad (2)$$

$$\mathbf{S/L} = K[\,(B/L)^b, M^c, (g,L/V^2)^f, (V^2 I / L^3 W)^g, (tV/L)^h\,] \quad (3)$$

$$\boldsymbol{\rho} \mathbf{L^2 V^2/W} = K[\,(B/L)^b, M^c, (g,L/V^2)^f, (V^2 I / L^3 W)^g\ tV/L)^h\,] \quad (4)$$

$$\mathbf{TV/L} = K[\,(B/L)^b, M^c, (g,L/V^2)^f, (V^2 I / L^3 W)^g, (tV/L)^h\,] \quad (5)$$

2.3 Test Planning

The test envelop, test points and test sequence are decided on the basis of some of the known ranges of variation of some of the independent variables. The specific test points indicate the actual values of the corresponding independent variables at which the test are carried out. The test sequence indicates the sequence in which the trials are conducted. Test points, test sequence and the corresponding dimensionless ratios (π-terms) are given in table 1.

Table 1. Test Planning

Sr. No	π- Terms	Test Envelope	Test Points	Test Sequence
1	$\pi 1 = B/L$	Constant	Constant	Constant
2	$\pi 2 = M$	5%to 9%	5,6,7,8,9	4,2,5,3,1
3	$\pi 3 = gL/V^2$	Constant	Constant	Constant
4	$\pi 4 = V^2I/L^3W$	4.63E-07 to 8.34E-07	4.63E-07, 5.21E-07, 5.96E-07 6.95E-07, 8.34E-07.	4,2,5,3,1
5	$\pi 5 = tV/L$	Constant	Constant	Constant

2.4 Selection and Calibration of Instruments

All experiments contain errors, which may be either large or negligibly small. Time and money may be wasted when uncertainties are ignored or roughly estimated. Hence, appropriate selection of instruments should be made for the measurement of various dependent and independent variables involved in the system. Also the specifications of instrument should be such that it covers the range of variation in the parameter to be measured at the permissible level of error (Schenck , 1961). To establish and take care of the errors in the measurement, the instruments used should be calibrated.

2.4.1 Necessity of designing a special power measuring system for measurement of force

The process of compressing lint cotton to form a bale is a very complex phenomenon. As soon as the platen starts moving from its topmost position, it is subjected to frictional load of mechanical power transmission system. The moment when the platen makes contact with the upper surface of the lint cotton, the platen starts compressing lint cotton. For the initial almost 50 % of the travel, the load is likely to be approx. 25 % of the maximum load. Subsequently the load is likely to rise non-linearly. During the last phase of compression, the load rise is most likely to be very steep. Therefore it is required to design and establish such a measurement technique which can measure this shock load. There are various techniques to measure load like the load cells, proving ring, etc. but these techniques were not found suitable to measure this steep rise in load.

2.4.2 Electromechanical force measuring system

A electronic measurement system is designed and developed which can measure force of compression for a set of independent parameters. This system is PC BASED and the system is plotting the graph of power versus time on the PC monitor at every preset value of time (from few microsecond to few mili seconds).

2.4.3 Measurement Technique

The Power dissipation in the motor which is given by VI cosφ varies according to the load variation. Where the Voltage will remain nearly same to the load variation, again the cosφ and power factor is fixed for particular motor (Thereja, 1998). So the variable parameter in the power equation is only I (current).

Power = VI cosφ, where V and Cos φ are Constant therefore C = V cosφ .Power = C x I

So by monitoring the current through the motor, we can monitor the power. This monitoring technique is easy to implement and the corresponding power variation can be easily monitored on the PC. In this technique, the current transformer is connected in series (Lowdin, 1985) with the motor, which converts the current from 20A to 100mA as shown in circuit diagram 1. The current is a sinusoidal wave, so the value, which we are measuring, is in the rms value. To convert RMS to DC level, converter is implemented so that the analog to digital converter gets the DC level, which is proportional to motor current.

The ADC (Analog to Digital Converter) connects this DC level to its equivalent digital signal (Gaokar, 1989), which is readable for the PC (or analog digital machine). This current equivalent is taken as an input to the PC and entering the values of V and cosφ. The computer will process this data and calculate the power, which will be displaced on the monitor.

The PC is plotting the power versus time waveform on its monitor. The direct relationship as well as the graphical presentation will appear on the computer screen. The sampling rate of the ADC is 5 KHz and is taken for the 200µs time interval. Hence its resolution is very high. Even the minor changes in the power can be monitored by this system. Software required for this measurement is developed (Kanetkar, 2002).

2.4.4 Calibration of Electronic measurement system

Calibration is nothing but checking of an instrument over its range against a known standard. Calibration improves the performance of instrument having poor accuracy and good precision. Replication technique is used for calibration of the instruments (Schenck, 1961). Calibration curve is plotted which is further used with the instrument to change scale to correct readings.

The current transformer is calibrated in different conditions i.e. for different loads like resistive and inductive. The components used in the system are calibrated with the standard components. A Current transformer (20A:100mA) was designed and fabricated as it is not a standard one also a setup was made in the laboratory for observing the behavior of the CT.

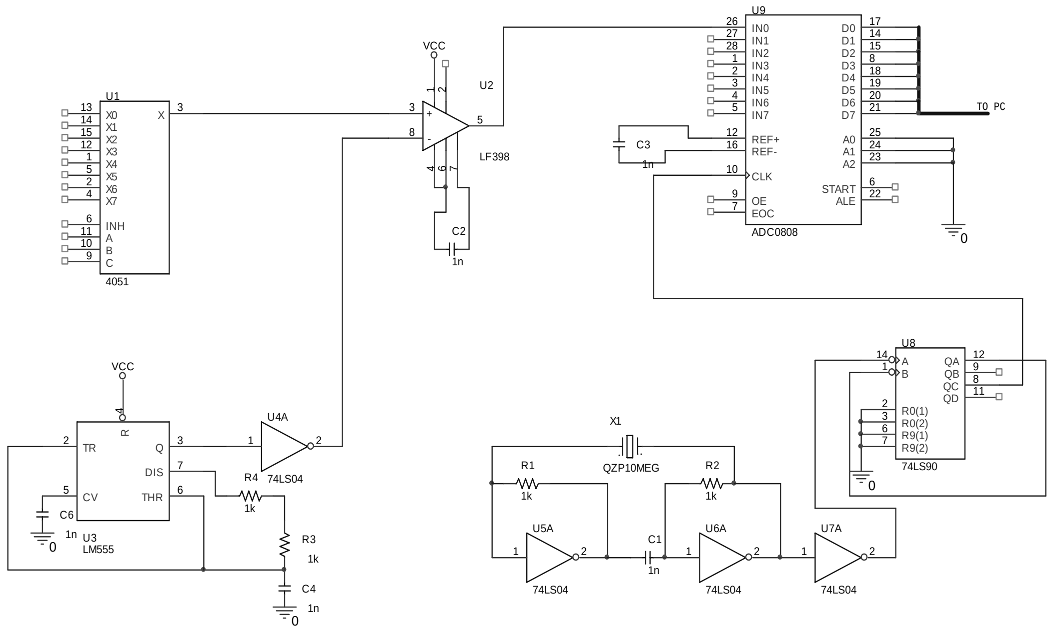

Figure 1 Circuit Diagram of Power measurement Technique

Figure 3. Experimental Set Up

The Calibration curve for current transformer plotted on the basis of calibration results is shown in figure 2.

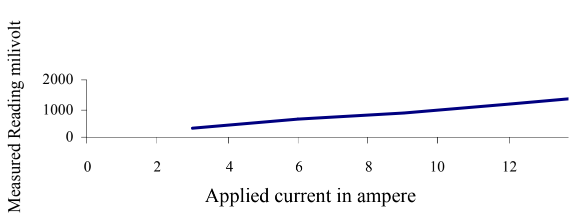

Figure 2 Calibration curve for current transformer

2.5 Experimental Setup

The experimental set up is shown in figure-3. It consists of an instrumented mechanical press having box size of 1200x480x1900mm for lint cotton and is operated by 10 hp; 1500 rpm, induction motor. The energy input to the machine is measured by a specially designed system interfaced with computer through Analog Digital card. The required hardware like 230volt potential transformer, 20amp current transformer, PCB, AD card and software for interfacing etc. are prepared. The experimentation was conducted as per test plan. The computer displays power consumed versus time in a graphical form for complete compression.

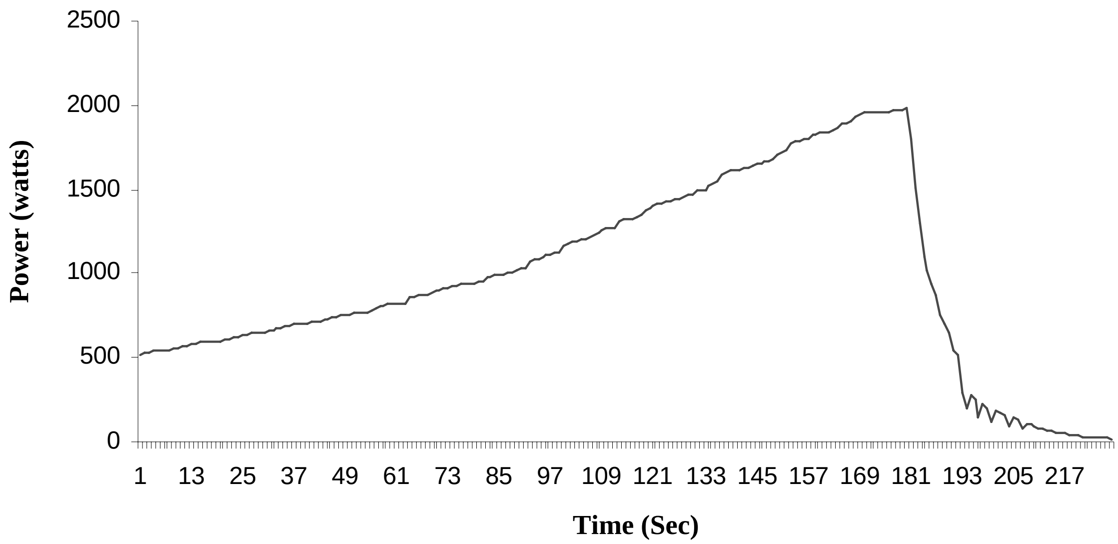

Figure 4 Experimental graph of power versus time

2.6 Observations and calculations

The force and energy of compression of lint cotton, density of compressed bale, platen travel during compression and total time of compression are evaluated on the basis of readings taken during experimentation, which was performed on motorized screw type bale making machine for compressing lint cotton by changing various physical quantities affecting the compression process. The power measuring system records power values in milliseconds. The sample calculation for evaluating the values of force and energy of compression of lint cotton, are shown here for weight of lint cotton 90kg and moisture content in lint cotton 5% which are independent variables.

2.6.1 Force of Compression

The following steps were followed for determination of force of compression. The graph of power (observed) in watts versus time was plotted, which is shown in figure 4.

This power (observed) was converted into power in kgf-m. The electric motor generated torque (Ti) was calculated from measured power readings in kgf-m and angular velocity using the following expression

$$\text{Torque} = I\frac{d^2\theta}{dt^2} \qquad (6)$$

I – Moment of Inertia of Mechanical Power Transmission system.

Then the following expression was used for estimation of force of compression (Black et. al.,1981).

$$T_i - I\, d^2\theta/dt^2 - Wd/2x \tan(\alpha+\phi) \times 1/G \times 1.2 = 0 \quad - (7)$$

T_i - Torque input at motor, W – force in kgf,
θ - Angular velocity rad, α - lead angle,
I - Equivalent moment of inertia of mechanical power transmission system
d - Diameter of screw, ϕ - friction angle

The detail calculations of various parameters in the equation are given in table 2 .Figure 5 shows maximum force and total time of compression for the sample of 90 kg and 5% moisture content.

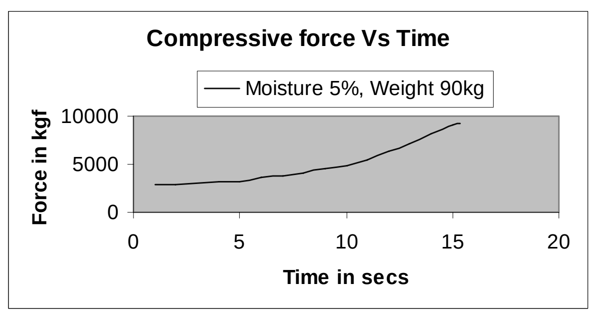

Figure 5 Graph of compressive force versus Time

Table 2. Estimation of Force of compression for the sample of 90 kg weight and 5% moisture content in lint cotton

Time in secs	Power Watts (Expt.)	Power in kgfm/sec	RPM	Angular speed, ϖ	Ele. Motor Torque (Ti) kgf-m	M. I. of transmission system torque kgf-m	Frictional torque kgf-m	Comp. Force W in kgf
1	1860	186.99	1498	156.87	1.19	$-4.9\text{x}10^{-3}$	$-4.2\text{x}10^{-4}$	2818
2	1920	193.00	1496	156.66	1.23	$-4.9\text{x}10^{-3}$	$-4.2\text{x}10^{-4}$	2932
3	2010	202.00	1494	156.45	1.29	$-4.9\text{x}10^{-3}$	$-4.2\text{x}10^{-4}$	3054
4	2100	211.13	1492	156.24	1.35	$-4.9\text{x}10^{-3}$	$-4.2\text{x}10^{-4}$	3196
5	2220	233.19	1490	156.03	1.49	$-4.9\text{x}10^{-3}$	$-4.2\text{x}10^{-4}$	3526
6	2355	236.76	1488	155.82	1.52	$-6.1\text{x}10^{-3}$	$-4.2\text{x}10^{-4}$	3599
7	2520	253.35	1485	155.51	1.63	$-6.1\text{x}10^{-3}$	$-4.2\text{x}10^{-4}$	3859
8	2700	271.45	1483	155.30	1.75	$-4.9\text{x}10^{-3}$	$-4.2\text{x}10^{-4}$	4139
9	2910	292.56	1481	155.09	1.89	$-6.1\text{x}10^{-3}$	$-4.2\text{x}10^{-4}$	4472
10	3180	319.70	1478	154.77	2.06	$-6.1\text{x}10^{-3}$	$-4.2\text{x}10^{-4}$	4873
11	3600	361.93	1476	154.57	2.34	$-4.9\text{x}10^{-3}$	$-4.2\text{x}10^{-4}$	5530
12	4080	410.19	1474	154.35	2.66	$-6.1\text{x}10^{-3}$	$-4.2\text{x}10^{-4}$	6288
13	4650	467.49	1471	154.04	3.03	$-6.1\text{x}10^{-3}$	$-4.2\text{x}10^{-4}$	7161
14	5265	529.32	1469	153.83	3.44	$-4.9\text{x}10^{-3}$	$-4.2\text{x}10^{-4}$	8125
15	5850	588.14	1467	153.62	3.83	$-4.9\text{x}10^{-3}$	$-4.2\text{x}10^{-4}$	9045
15.33	5949	598.09	1465	153.41	3.90	$-4.9\text{x}10^{-3}$	$-4.2\text{x}10^{-4}$	9210

2.7 Test Data Checking and Rejection

Experimental model is developed with the help of computer programme to evaluate values of exponent's b, c, f, g, h and the curve fitting constant K involved in equations (1) to (5) using MATLAB software (Agrawal et al., 2003). Another technique based on Artificial Neural Network is used for modeling. An Artificial Neural Network (ANN) is an information-processing paradigm that is inspired by the way biological nervous systems such as the brain processes information (Rumelhart & Williams, 1986). It is found that the values obtained by calculation are similar to those obtained by MATLAB and ANN.

2.8 Data analysis

The experimental model established for determining the dependent variables of screw type bale making machine are checked for goodness of fit by applying a student t test (Spiegel, 1980). The result of the test have revealed that the estimated T value of student t test for all the models for their dependent dimensionless ratios for the significance range are within the range of the standard tabulated values of students t test T at 5% level of significance and corresponding degrees of freedom .This confirms the fit between the observed values and the estimated values and that the fitness of these exponential models is good.

3. CONCLUSION

The paper has explained the procedure of experimentation and the measurement technique used for measuring the compressive force involved during the compression of cotton using a screw type mechanical press. Figure 1 explains the Electro mechanical system designed for measuring force. The graph obtained from the system shows that force rises steeply at the end of the compression process.

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