Calibration Of Wattmeter for the Measurement of Process Torque in an Experimental Brick Extruder

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Abstract

It has been noted through literature review that no systematic efforts have been made in the past to evolve the generalized theoretical as well as experimental models for motorized auger type brick extrusion machines for extruding flyash-clay bricks. Therefore, it was necessary to generate design data to provide a systematic basis for designing motorized auger type brick extrusion machine. An experimental brick extruder was designed and fabricated for carrying extensive experimentation to generate design data for motorized auger type brick extrusion machine, extruding flyash-clay bricks.

During experimentation the measurement of torque on the auger screw in the process of extrusion of flyash-clay bricks was tried with the help of wattmeter.

This paper reports the methodology of calibration of wattmeter (replication technique) used for the measurement of process torque in the process of extrusion of flyash-clay bricks in an experimental extruder. A calibration setup specially fabricated for the purpose has been explained. The statistical tools are applied to prove that the measurement of torque by wattmeter gives a reasonably accurate measure of torque on the auger screw of a motorized experimental extruder. The calibration curve for wattmeter plotted on the basis of calibration results has been presented.

EXPERIMENTAL BRICK EXTRUDER

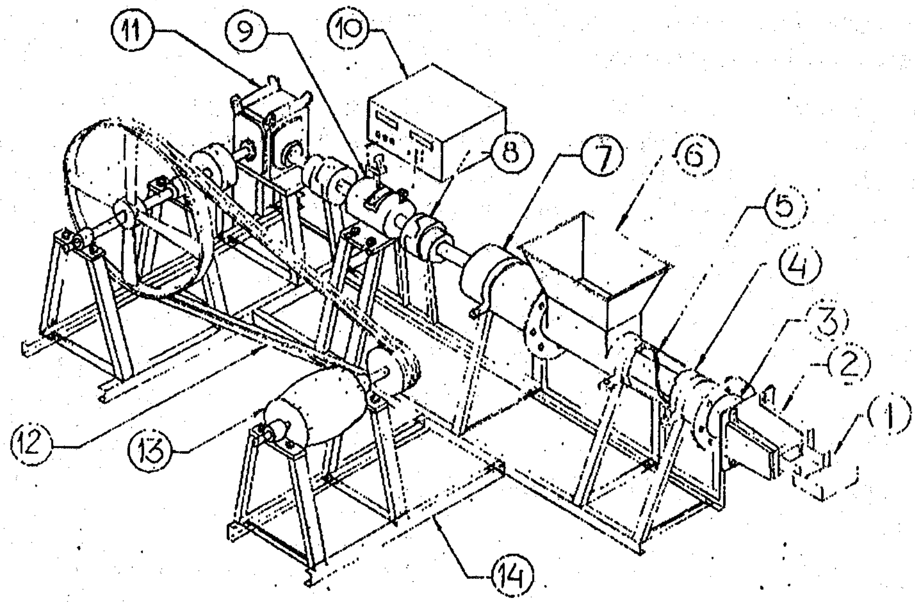
The salient features and working principle of a specially fabricated experimental extruder having 1:3 scaled reduction of the full size motorized auger type brick extrusion machine are given below -

The isometric layout of an experimental extruder is shown in figure 1. A 5 h.p., 1440 rpm, three phase induction motor (13) is used to drive the experimental extruder. The speed of auger shaft of experimental extruder is taken as 24 rpm. A speed reduction from 1440 to 24 rpm has been achieved through a combination of V-belt drive (12) and worm gear reducer (11). A speed reduction of 1:4 is obtained with the help of V-belts. The larger pulley is mounted on a shaft supported by two brackets. The shaft on which larger pulley is mounted is coupled to the input shaft of a worm gear reducer with the help of a flange coupling. A speed reduction of 1:15 is achieved through worm gear reducer giving a speed of 24 rpm to the auger screw.

The output shaft of worm gear reducer is coupled with the shaft of a torque sensor (9), the other end of which is further coupled with the auger screw. Flexible couplings (8) are used to couple torque sensor shaft with the worm reducer shaft and auger screw. A torque sensor is used to measure the process torque on the auger screw during extrusion of brick column.

An auger screw (5) is supported at one end with the help of two taper roller bearings housed in the bearing housing (7). A properly prepared homogeneous mix of flyash and clay is fed through a hopper (6). Due to the rotation of auger screw the mix moves forward towards cone (3) and then through the die

(2). The uniformly shaped brick column extrudes through a die which is connected to the cone. It is then collected on a simple cutting tray (1) having a slot through which a piece of wire can be inserted for cutting the bricks by wire-cut method.



Measurement of process torque

The basic criteria considered for optimizing the flyash-clay brick extrusion are,

1. Rate of extrusion of bricks.
2. Green strength of brick.
3. Torque on the auger screw i.e. the process torque.

During experimentation, the rate of extrusion was determined by measuring the length of brick column extruded per unit time and the green and baked strength of brick was measured on compression testing machine. It was attempted to measure the process torque for extruding bricks with the help of in-line rotating torque sensor. It was connected in between the output shaft of a worm gear reducer and the auger shaft with the help of flexible couplings. A digital torque indicator of the torque sensor gives a record of the process torque.

It was observed during experimental trials that the torque sensor continuously malfunctioned giving extremely fluctuating and erratic readings. Hence, an alternate method of measurement of process torque was adopted in which the torque on the auger screw was measured by connecting a wattmeter to the three phase induction motor. The wattmeter measures the power taken up by the motor for extrusion of brick column which in turn gives a record of torque on the auger screw of the experimental extruder extruding flyash-clay bricks.

Calibration of wattmeter

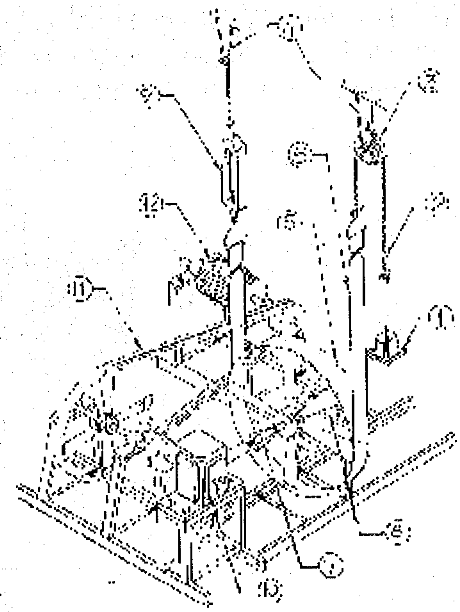
It was necessary to calibrate the wattmeter against the known torque. A calibration setup was specially fabricated and installed. The wattmeter was suitably calibrated and the calibration curve as shown in figure 3 was obtained.

Description of calibration setup

The isometric layout of the calibration setup is shown in figure 2.

A 5 h.p., 1440 rpm, three phase induction motor (12) is used to drive the flat pulley of the calibration setup. The speed of the flat pulley is taken as 24 rpm. A speed reduction from 1440 rpm to 24 rpm has been obtained by a combination of the V-belt drive (11) and the worm gear reducer (10) having speed reduction ratio of 1:4 and 1:15 respectively.

A flat belt dynamometer was specially fabricated for the calibration of wattmeter. A flat pulley (6) is mounted on a M.S. shaft (7). The shaft is supported on a pedestal bearing mounted on a bracket (8). The shaft on which flat pulley is mounted has been coupled to the output shaft of a worm gear reducer.



A leather belt (5) is passed over a flat pulley. A spring balance (9) is hooked to one end of the flat belt to measure the tension on the slack side. The other end of the flat belt is connected to rope (2) which passes over a guiding pulley with bracket (3) mounted on ceiling hooks (4). A weight pan (1) is attached to the other end of the rope. The location of hooks is fixed in such a way that the angle of lap of the belt on the flat pulley is 1800. A wattmeter to be calibrated is connected to the motor through proper electrical connections.

Procedure of calibration

The following procedure is adopted for the calibration of wattmeter -

i) Determination of no load torque : The power taken up by the motor which is measured by wattmeter represents the sum of the power required to overcome the belt friction and the losses in motor, V-belt drive and the worm gear reducer.

In order to account for the power losses in motor, V-belt drive and worm gear reducer, the wattmeter readings are taken at no load condition. The drive motor is switched on and wattmeter reading is noted. These no load readings are replicated for 30 times and the average no load torque T_0 is calculated which is found out to be 55.953 kg.m.

ii) Calibration for frictional torque : A known torque T_A is applied by keeping the weights in the pan. Initially, a load of 23.1 kg is kept in the pan. The drive motor is switched on. The power taken up by the motor to overcome the applied torque is measured by the wattmeter. The wattmeter reading is noted. Simultaneously, the speed of the flat pulley is measured by tachometer and the spring balance reading is also recorded. The motor is switched off. This procedure is replicated for 30 times for 23.1 kg load. From the wattmeter readings, the measured torque T_M is determined. The belt frictional torque T is obtained as a difference between the torque measured by wattmeter T_M and the no load torque T_0, i.e.,

$$T = T_M - T_0$$

The above procedure is repeated for other loads like 44.7 kg, 64.7 kg and 84.7 kg by replicating the readings for 30 times for each load and estimating the frictional torque T.

The torque measured by wattmeter T_M is calibrated against the known applied torque T_A. The readings of the calibration are given in table 1

Table 1 : Reading obtained during calibration of wattmeter

Check for normal distribution

The deviation between the applied torque T_A and the frictional torque T for 30 replicated samples at each applied torque was checked for its normal distribution. This has been checked by applying the area property of the normal distribution curve [S.C. Gupta and V.K. Kapoor 1984] and further confirmed by applying the Chi-square test [M. Ray and Har Swarup Sharma 1978] to each set of data obtained during calibration.

The area property of the normal distribution curve have revealed that the said deviation (T_A-T) is normally distributed as shown in table 2, since the observed frequency is found out to be nearly equal to or greater than the expected frequency for all sets of load applied.

(TABLE 2)

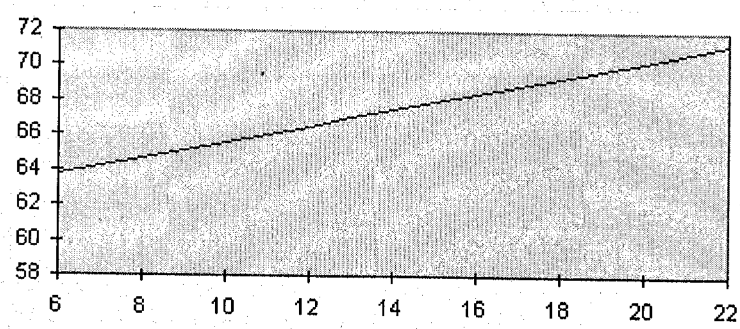
The Chi-square test

Each set of data is subjected to a Chi-square test with the null hypothesis that the fit between the actual applied torque and frictional torque measured by wattmeter is good. The results of the test have revealed that the estimated □2 value for each set of data (applied torque) is much less than the standard tabulated value of □2 at 5% level of significance and 29 degrees of freedom as shown in table 3.

This comparison leads to the conclusion that there is no cause to suspect the hypothesis and the fit between the actual applied torque and measured frictional torque is good, i.e. the null hypothesis may be accepted. This proves beyond doubt that the deviation between applied torque and measured frictional torque follows a normal distribution and the measurement of torque by wattmeter gives a reasonably accurate measure of torque during experimentation.

Calibration curve for wattmeter

The calibration curve for wattmeter plotted on the basis of calibration results is shown in figure 3.



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(Table 2)

Set No.	Applied load (kg)	Average deviation (T_A - T)	Standard deviation	Expected frequency			Observed frequency		
				- 1σ to + 1σ	- 2σ to + 2σ	- 3σ to + 3σ	- 1σ to + 1σ	- 2σ to + 2σ	- 3σ to + 3σ
1	23.100	0.3897	0.5790	20	28.5	29.5	20	28	30
2	44.700	0.0088	0.35366	20	28.5	29.5	22	29	30
3	64.700	1.1468	0.81064	20	28.5	29.5	22	29	29
4	84.700	9.6626	0.82839	20	28.5	29.5	23	29	29

(Table 1)

Set No.	Applied load (kg)	Average applied torque T_A (kg.m)	Average measured torque T_M (kg.m)	No load torque T_O (kg.m)	Average frictional torque $T = T_M - T_O$	Average Deviation (T_A - T)
1	23.100	6.3023	61.8656	55.953	5.9126	0.3897
2	44.700	12.2878	68.2320	55.953	12.2790	0.0088
3	64.700	17.3593	72.1655	55.953	16.2125	1.1468
4	84.700	22.5230	68.8134	55.953	12.8604	9.6626

(Table 3)

Set No.	Applied load (kg)	Std. Tabulated χ^2 at 5 % significance level and 29 degrees of freedom	
1	23.100	42.557	2.677
2	44.700	42.557	0.301
3	64.700	42.557	3.527
4	84.700	42.557	29.954