

# Post harvest crop processing machine

K. S. Zakiuddin\*, J. P. Modak

(Priyadarshini College of Engineering, Nagpur, Maharashtra, India)

**Abstract:** Chaff is hay cut into small pieces for feeding to livestock. Chaff can be carried by manually operated machine and electricity operated machine. This paper presents experimental work executed for establishing mathematical model and simulation for chaff cutting operation establishment of mathematical model and its optimization. Has been established for responses of the system such as instantaneous resistive torque ( $\pi_{D1}$ ), number of cuts ( $\pi_{D2}$ ) and process time ( $\pi_{D3}$ ). Model for dependent term instantaneous resistive torque:  $\pi_{D1}$ . The models are:  $\frac{D}{gl} T_c = 1.645 \times 10^3 (\pi_1)^{3.8074} (\pi_2)^{0.5141} (\pi_3)^{-0.4521} (\pi_4)^{1.686} (\pi_5)^{2.3237} (\pi_6)^{0.8162} (\pi_7)^{-0.4189} (\pi_8)^{-0.3840}$ . Model for dependent term number of cut (C)  $\pi_{D2}$ :  $\pi_{D2} = 0.6449 (\pi_1)^{0.0001} (\pi_2)^{-0.0146} (\pi_3)^{0.3471} (\pi_4)^{1.0151} (\pi_5)^{0.2781} (\pi_6)^{0.1233} (\pi_7)^{0.9701} (\pi_8)^{0.4773}$ . Model for the dependent term process time,  $\pi_{D3}$ :  $\pi_{D3} = 43.43 (\pi_1)^{0.0001} (\pi_2)^{0.1753} (\pi_3)^{0.0012} (\pi_4)^{0.0001} (\pi_5)^{0.0505} (\pi_6)^{0.2508} (\pi_7)^{1.0008} (\pi_8)^{0.0004}$ . This paper discusses about the applications for pedal power technology.

**Keywords:** manually energized flywheel motor, spiral jaw clutch, fodder

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## 1 Introduction

Developing countries like India are facing problems of power storage due to rapid industrialization, like non availability of power in interior areas and large scale unemployment of semi-skilled worker. In the context of the present condition in India of power shortage and exhaustion of coal reserves and unemployment, crop cutting machine is very necessary. As far as manually operated machine is concerned for the operator the machine is physically demanding energy and postural requirements and is commonly regarded as source of drudgery. In the recent years, a human-powered process machine has been developed for brick making (Modak, 1998) wood turning, finger type torsionally flexible clutch for a low capacity manually energized chemical unit and battery charging (Modak, 1993). The machine consists of a human powered flywheel motor using a

bicycle-drive mechanism with speed increasing gearing and a flywheel, which drives the process unit through a clutch and torque-increasing gearing (Dhakate, 1995).

## 2 Materials and methods

### 2.1 Working principle of fodder chopper machine

Working principle of manually energized fodder chopper machine is described as was shown in Figures 1 and 2. Each rider accelerates the flywheel to the speed of 600 r/min in 1 min (Alexandrove, 1981). The size flywheel is 1 m in rim diameter, 10 cm in rim width and 2 cm in rim thickness such a flywheel when it is energized to the speed of 600 r/min stores energy. In this machine, first energy is stored in the flywheel by accelerating it to a desired speed by pedal through chain and gear drive. When flywheel attains the desired speed, it is connected to the torque amplification gear by engaging a spiral two jaw clutch (Gupta, 1997). The energy stored in flywheel is supplied at the required rate to shaft of the chaff cutter and cutting of fodder, to obtain small pieces of fodder. A free wheel is used between pedals and the flywheel to prevent the back flow of

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\***Corresponding author:** K. S. Zakiuddin, Priyadarshini College of Engineering, Nagpur, Maharashtra, India. Email: qszaki1@rediffmail.com.

energy from flywheel to pedals. A special jaw clutch is used in this machine in place of conventional friction clutch. A manually energized fodder chopping machine is being developed in absence of any design data.

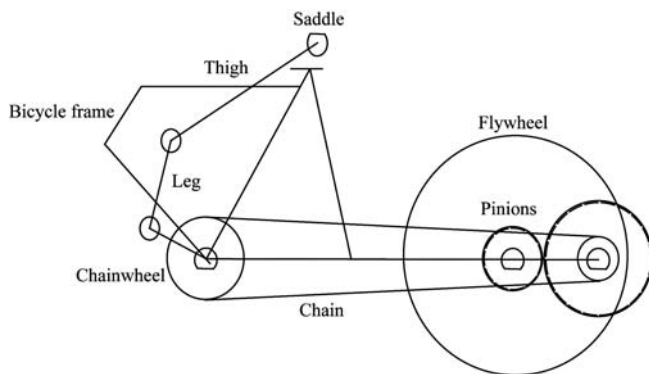


Figure 1 Energy unit and the transmission system

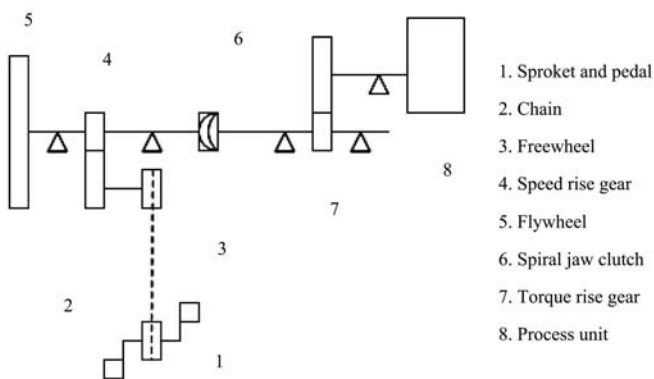


Figure 2 Schematics of pedal powered energized crop cutter.

## 2.2 Design of experimentation:

Generalized experimental models for resistive torque, number of cuts, and process time are established adopting methodology of experimentation (Schenk, 1980). It is planned to generate design data by performing extensive experimentation by varying physical quantities encountered in the process of chopping over the widest range. The planning of experimentation is carried out by using the classical plan of experimentation (Schenk, 1980). The response data is collected based on the entire generalized models.

The methodology of experimentation is briefly stated as follows:

- 1) Identification of all independent, dependent and extraneous variables
- 2) Reduction of variables through dimensional analysis;
- 3) Determination of test envelopes, test points and test

sequence,

- 4) Design of an experimental setup;
- 5) Execution of experimentation to generate the experimental data;
- 6) Purification of experimental data;
- 7) Formulation of the mathematical model of the dimensional equation;
- 8) Artificial neural network simulation.

## 3 Results and discussion

### 3.1 Dimensional analysis

The process variables for manually energized fodder chopper were identified and are tabulated in Table 1. Dimensional analysis was carried out to established dimensional equations, exhibiting relationships between dependent  $\pi$  terms and independent  $\pi$  terms using Buckingham  $\pi$  theorem.

Table 1 Dimensional analysis

Sr. No.	Description	Types of variables	Symbols	Dimensions
1	Tip diameter of blade	Independent	D	L
2	Hub diameter	Independent	D	L
3	Acceleration due to gravity	Independent	G	$LT^{-2}$
4	No. of blades	Independent	N	-
5	Young modulus of elasticity of cutting blade	Independent	E	$ML^{-2}L^{-1}$
6	Width of cutting blade	Independent	$W_b$	L
7	Thickness of cutting blade	Independent	$L_b$	L
8	Cutting blade angle	Independent	A	-
9	Equivalent moment of inertia of flywheel	Independent	I	$ML^2$
10	Angular velocity of flywheel	Independent	$\Omega$	$T^{-1}$
11	Gear ratio	Independent	$\tau_G$	-
12	Sp time instant during cutting operation	Independent	$t_c$	T
13	Kinetic Energy of flywheel	Independent	E	$ML^2T^{-2}$
14	Instantaneous torque on cutting blade	Dependent	$T_c$	$ML^2T^{-2}$
15	No. of cuts during cutting	Dependent	$C_p$	-
16	Process time for cutting chaff	Dependent	$t_p$	T

Note: M-mass, L-length, T-time.

Dimensional analysis can be used primarily as an experimental tool to combine many experimental variables into one. The main purpose of this technique is making experimentation shorter without loss of control. Applying Raleigh's method the dimensional equation for resistive torque, number of cuts, process time is formulated:

**Resistive torque:**

$$T_c = f[(dW_b L_b / D^3), (D^4 / gI)E, \alpha, \tau_G, n, (\sqrt{(D/g)}\omega), (\sqrt{(g/D)t_c}), (D/2g)\omega_F^2]$$

$$(D/gI)T_c = f[(dW_b L_b / D^3), (D^4 / gI)E, \alpha, \tau_G, n, (\sqrt{(D/g)}\omega), (\sqrt{(g/D)t_c}), (D/2g)\omega_F^2] \quad (1)$$

**Number of cuts:**

$$C = f[(dW_b L_b / D^3), (D^4 / gI)E, \alpha, \tau_G, n, (\sqrt{(D/g)}\omega), (\sqrt{(g/D)t_c}), (D/2g)\omega_F^2]$$

$$\sqrt{(D/g)}Cp = f[(dW_b L_b / D^3), (D^4 / gI)E, \alpha, \tau_G, n, (\sqrt{(D/g)}\omega), (\sqrt{(g/D)t_c}), (D/2g)\omega_F^2] \quad (2)$$

**Process time for cutting (t<sub>p</sub>):**

$$Tp = f[(dW_b L_b / D^3), (D^4 / gI)E, \alpha, \tau_G, n, (\sqrt{(D/g)}\omega), (\sqrt{(g/D)t_c}), (D/2g)\omega_F^2]$$

$$\sqrt{(D/g)}Tc = f[(dW_b L_b / D^3), (D^4 / gI)E, \alpha, \tau_G, n, (\sqrt{(D/g)}\omega), (\sqrt{(g/D)t_c}), (D/2g)\omega_F^2] \quad (3)$$

**3.2 Test Planning**

This comprises of deciding test envelope, test points, test sequence and experimental plan for the deduced sets of independent π terms.

The test envelope comprises of complete range encompassed by the individual independent π term. So, it is now necessary to ascertain the complete range over which the entire experimentation is to be carried out. In this test, we can estimate the ranges only for independent six π-terms.

The spacing of the test points within the test envelop is selected not for getting a ‘symmetrical’ or ‘pleasing’ curve but to have every part of our experimental curve map the same precision as every other part. Thus, the concept of proper spacing is now replaced by permissible spacing of the test points. Similarly, for all other π terms the test points are decided by permissible spacing rather than by the proper spacing. The choice of test sequence is decided by nature of experimentation viz. reversible or irreversible. The independent variables are varied from one extreme to another in a sequential plan or in a perfectly random fashion in a random plan.

**3.3 Observations**

The recorded observations are presented in the Table 2. Table 2 shows the relationship between dependent dimensionless ratios and the independent dimensional ratios. Figures 3 and 4 show the plots for the variations in the flywheel speed and chaff cutter speed for independent variables.

**Table 2 Test envelope, test points and test sequence**

Sr.No.	Ratio	Test Envelope (Range)	Test Points	1	2	3	4	5	6
		Test Sequence		I	II	III	IV	V	VI
1	$\pi_1 = \left(\frac{dW_b t_b}{D^3}\right)$	5.33×10 <sup>-5</sup>	Constant						
2	$\pi_2 = \left(\frac{D^4}{gI}\right) \cdot E$	1.46×10 <sup>9</sup>	Constant						
3	$\pi_3 = \sqrt{(D/g)}\omega$	Test envelope, test points and test sequence cannot be defined as ω cannot be predefined it readings will be noted at instant during experimentation							
4	$\pi_4 = \tau_G$	1, 2, 3, 4.		3	3	3	3	4	3
5	$\pi_5 = \alpha$	0.122				Constant			
6	$\pi_6 = n$	2 – 3		2	2	2	2	2	3
7	$\pi_7 = \frac{D}{2g} \omega_F^2$	35.41 141.66		35.41	62.96	98.25	141.66	62.96	62.96
8	$\pi_8 = \sqrt{(g/D)t_c}$	Test envelope, test points and test sequence cannot be defined as t <sub>c</sub> cannot be predefined it readings will be noted at instant.							

Note: ω<sub>F</sub>= angular velocity of flywheel.

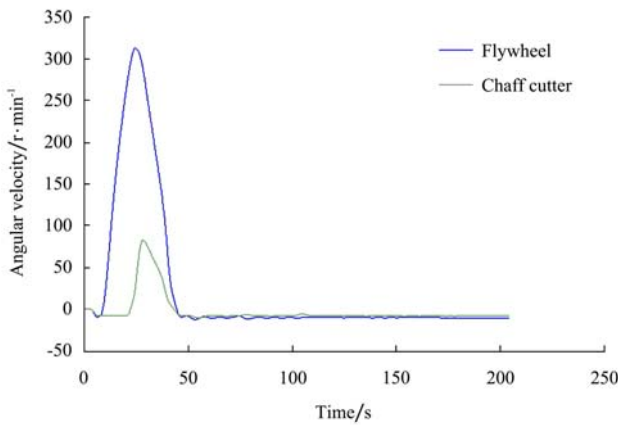


Figure 3 Speed plot of flywheel and cutter for independent variables ( $\tau_G = 3, n=2$ , speed of flywheel  $N=300$ )

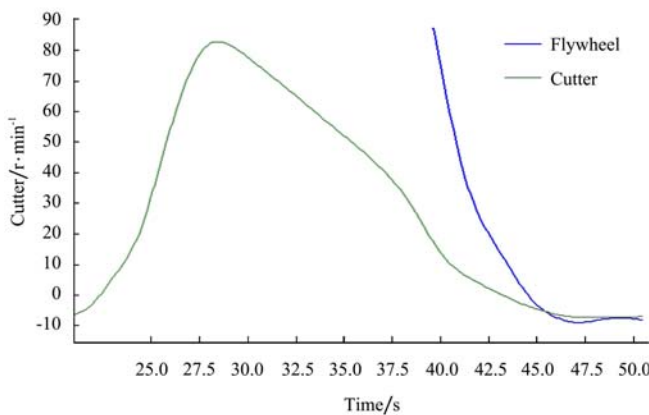


Figure 4 Speed plot of cutter for independent variables  $\tau_G = 3, n=2$ , speed of flywheel  $N=300$

### 3.4 Formulation of experimental data based models

A probable exact mathematical form for the dimensional equations could be represented by solving this problem by curve fitting technique (Spiegel, 1998).

An approximate generalized experimental data based models for the pedal operated energized fodder cutting machine system has been established for responses of the system such as instantaneous resistive torque ( $\pi_{D1}$ ), number of cuts ( $\pi_{D2}$ ) and process time ( $\pi_{D3}$ ).

Model for dependent term instantaneous resistive torque:  $\pi_{D1}$

The models are:

$$\frac{D}{gI} T_c = 1.645 \times 10^3 (\pi_1)^{3.8074} (\pi_2)^{0.5141} (\pi_3)^{-0.4521} (\pi_4)^{1.686} (\pi_5)^{2.3237} (\pi_6)^{0.8162} (\pi_7)^{-0.4189} (\pi_8)^{-0.3840} \quad (4)$$

Model for dependent term number of cut (C)  $\pi_{D2}$ :

$$\pi_{D2} = 0.6449 (\pi_1)^{-0.0001} (\pi_2)^{-0.0146} (\pi_3)^{0.3471} (\pi_4)^{-1.0151} (\pi_5)^{0.2781} (\pi_6)^{0.1233} (\pi_7)^{0.9701} (\pi_8)^{0.4773} \quad (5)$$

Model for the dependent term process time,  $\pi_{D3}$ :

$$\pi_{D3} = 43.43 (\pi_1)^{0.0001} (\pi_2)^{-0.1753} (\pi_3)^{-0.0012} (\pi_4)^{-0.0001} (\pi_5)^{-0.0505} (\pi_6)^{-0.2508} (\pi_7)^{1.0008} (\pi_8)^{-0.0004} \quad (6)$$

### 3.5 Artificial neural network simulations

Different software tools have been developed to construct ANN. MATLAB being internationally accepted tool, has been selected for developing ANN for the complex phenomenon. The various steps followed in developing the algorithm to form ANN are as follows:

1) The observed data from the experimentation is separated into two parts viz. input data or the data of independent  $\pi$  terms and the output data or the data of dependent  $\pi$  terms. The input data and output data are stored in test.txt and target.txt files respectively.

2) The input and output data are then read by the using the DLMREAD function.

3) In preprocessing step the input and output data are normalized.

4) Through principle component analysis the normalized data are uncorrelated. This is achieved by using precpa function. The input and output data is then categorized in three categories viz. testing, validation and training. The common practice is to select initial 75% data for testing, last 75% data for validation and middle overlapping 50% data for training. This is achieved by developing a proper code.

5) The data is then stored in structures for testing validation and training.

6) Looking at the pattern of the data feed-forward back-propagation type neural network is chosen.

7) This network is then trained using the training data. The computation errors in the actual and target data are computed. Then the network is simulated as is shown in Figures 5, 6 and 7. The errors in the target (T) and the actual data (A) are represented in graphical form.

8) The uncorrelated output data is again transformed onto the original form by using poststd function.

**Table 3 Comparison between observed and computed values of dependent  $\pi$  term**

Dependent $\pi$ term	$\pi_{D1}$	$\pi_{D2}$	$\pi_{D3}$
Experimental	0.1773	33.588	63.276
A.N.N	0.1866	32.965	63.337
Empirical	0.2155	34.069	63.042
Standard error of estimation	0.0260	3.390	0.639

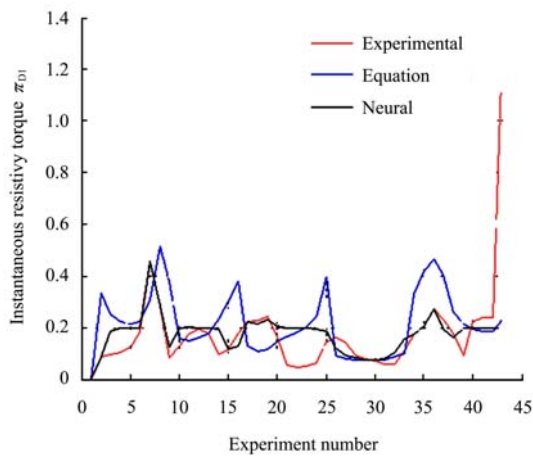


Figure 5 Comparison of experimental and computed data by A.N.N ( $\pi_{D1}$ )

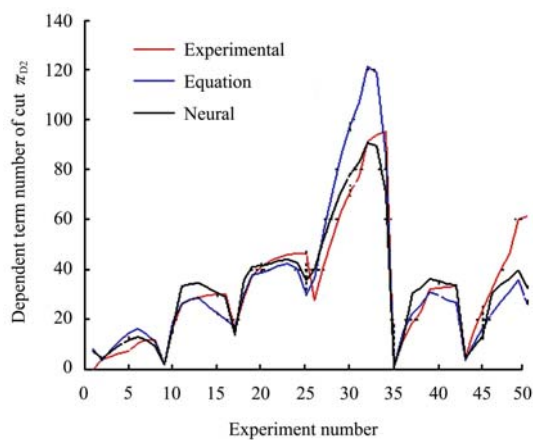


Figure 6 Comparison of experimental and computed data by A.N.N ( $\pi_{D2}$ )

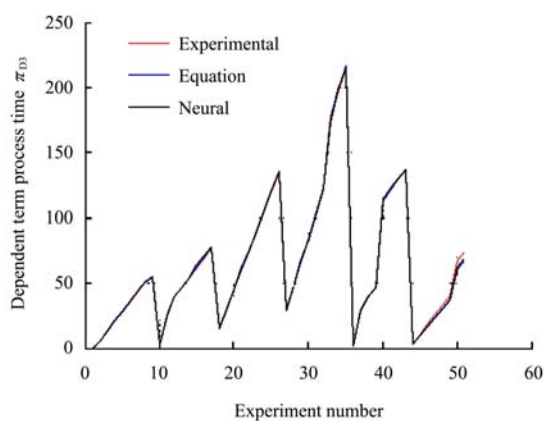


Figure 7 Comparison of experimental and computed data by A.N.N ( $\pi_{D3}$ )

#### 4 Conclusions

Empirical models to predict the performance of the manually energized fodder chopping machine to cut fodder were established and optimum values of various parameters were arrived at on the basis of experiments

involving the manually energized fodder chopping system.

A new theoretical approach of cutting the fodder from the manually energized fodder chopping machine is proposed. This hypothesis states that on engagement of the clutch, the speed of flywheel suddenly falls indicating energy loss. A part of this energy loss is subjected to decline because of the load torque acting on the blades due to persistent presence of cutting action.

It is further hypothesized that the cutting time is a function of available energy for cutting, resisting torque and average angular speed of the fodder chopper shaft the proposed flywheel motor can be used as an energy source for any process unit that can operate with its input element in a transient state of motion.

This flywheel motor is applied to brick making, low head water pumping and wood turning the performance is found to be functionally satisfactory and economically viable the flywheel motor can be used as an energy source for process unit that need have continuous operation and have an upper limit of about 3 h.P.

The mathematical models and an ANN developed for the phenomenon truly represents the degree of interaction of various independent variables which are made possible the only approach was adopted in this investigation.

The standard error of estimate of the predicted/computed values of the dependent variable is found to be very low. This gives authenticity to the developed mathematical models and an ANN.

The trends for the behavior of the models demonstrated by graphical analysis, sensitivity analysis are found complementary to each other. These trends are found to be truly justified through some possible physics of phenomenon.

This innovation in the machine will bring mechanization in agricultural engineering. The rural population including unemployed and unskilled women in addition to male may also get employment. Development of such an energy source which have tremendous utility in energizing many rural based process machines in places where reliability of availability of electric energy is much low.

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