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FORMATION AN EXPERIMENTAL DATA BASED MODEL FOR PIGEON PEA WOOD CHIPPER CUTTER OPERATED ON HUMAN POWERED FLYWHEEL MOTOR

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ABSTRACT

This paper presents the experimental approach towards formulation of an approximate generalized experimental data based model for wood chipper cutter energized by human powered flywheel motor (HPFM). Here input energy is supplied by operating a bicycle unit by using flywheel as a source of storing energy so this energy concept is refereed as human powered flywheel motor. Developing countries like India are facing problems of power shortage due to rapid industrialization coupled with limitations on additional power generation and non-availability of power in the interior area. In this context the sources of energy is human power operated systems which are considered to be one of the form of non-conventional energy sources. In this aspect, this paper aims at developing experimental data based model for Pigeon Pea stalk and as a agriculture residue for different variables involved in the design of wood chipping machine using HPFM.

Keyterms: Pigeon Pea, Wood Chipper, Experimental Model, Processing Machine, Flywheel, HPFM.

I. INTRODUCTION & OVERVIEW

Wood is an important source to human beings for many years & it is especially an integral part of the cultural, social and economic traditions of many societies. Vidarbha region is mostly agricultural area where Cotton stalk and pigeon pea as a wood is regular & easily available product. Here in this research these wood residues are used for making chips. Wood chips are pulped to make paper. Most of the papers are made from softwood trees such as fir, pine and arhar. The Pigeon Pea are also coming into the category of soft wood then this can be the extensively used for making papers even most of the paper manufacturing units are suing this types of wood as a raw material. Paper has been important to write and print on. Without it we would not have books, magazines or newspapers. Wood is one of the most important building materials. The machine consists of human powered flywheel motor as an energy source. The human powered flywheel motor comprises of subsystems like human powered process unit, appropriate clutch and transmission and a process unit. Energy unit consists of bicycle-drive mechanism with speed increasing gearing, appropriate clutch transmission and a flywheel. The operator pumps energy to the flywheel at a convenient input power level. After enough energy is stored, pedaling is stopped and the energy in the flywheel is made available to the process unit by engaging the clutch.

II. WORKING OF THE HUMAN POWERED FLYWHEEL SYSTEM

The operator drives the bicycle by pedaling the mechanism while clutch is in disengage position. The human power operated flywheel motor is energy source. This energy source energizes the process unit through clutch and transmission. The flywheel is accelerated and energized which stores some energy inside it. When the pedaling is stopped, clutch is engaged and stored energy in the flywheel is transferred to the process unit input shaft by means of clutch. The process unit is sliver cutting unit which comprises of feeder, four pairs of spring loaded rollers, sliver cutter, adjusting knobs, helical spur gear train, foundation frame and knuckle and pipe joint. Figure 1 depicts Schematic arrangement of human powered cutting unit. When the input shaft is rotated by means of energy transferred by the flywheel with the help of clutch, the wood or crop stem is fed and guided by the manually feeing process at the front end of process unit i.e. chipper cutting unit. When the wood is fed through the feeder of chipper cutting unit, it is come in contact with the rotating disc on which the three cutting blades are mounted, by positioning the cutter in downward direction the chips are cut from wood. The thickness of chip is adjusted by adjusting the position of wood by moving the chipper cutter up and down by means of studs fixed to the cutter frame. For continuous chip production the constant supply of wood stem has to maintain this helps in adjusting any size of wood chips [8].

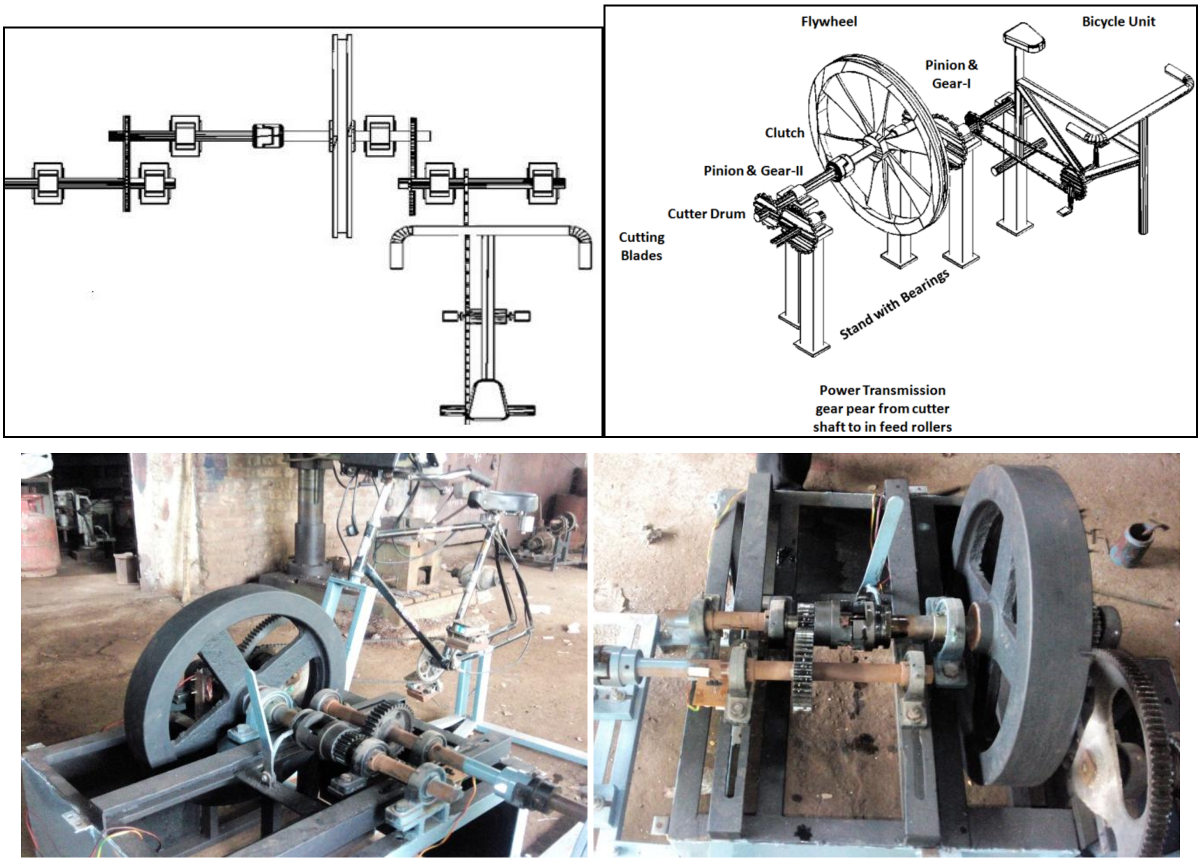

Figure 1. Human Powered Flywheel System

Figure 2. Wood Chipping System

Figure 3. Human Powered Flywheel System with Wood Chipping Unit

III. VARIABLES IDENTIFIED FOR FORMING EXPERIMENTAL DATA BASED MODEL

The process of wood chipping constitutes following dependent or the response variables:

(1) Instantaneous Torque, (2) Angular velocity of process unit and (3) Processing Time.

The various dependant and independent variables involved in the process of wood chipper unit are as shown in table below

Table no 2, Identification of Dependant & Independent Veriables

S.N.	Variables	Unit	$M^0L^0T^0$	Dependant/ Independent	Variable/ Constant
1	tp= Processing Time	Seconds	T	Dependant	Response Variable
2	Tp=Avg resistive torque	N-mm	ML2T-2	Dependant	Response Variable
3	Wo = output weight of chips	rev/ sec	T-1	Dependant	Response Variable
1	E_r= Flywheel Energy	N/mm^2	ML^2T^{-2}	Independent	Variable
2	ω_f = Speed of flywheel shaft	rev/ sec	T^{-1}	Independent	Variable
3	t_f = Time required of flywheel	Seconds	T	Independent	Variable
4	G = Gear ratio	-	-	-	Variable
5	g = acceleration due to gravity	mm/sec^2	LT^{-2}	Independent	Constant
6	E_m= modulus of elasticity of stem /material	N/mm^2	$ML^{-1}T^{-2}$	Independent	Constant
7	E_c= modulus of elasticity of cutter	N/mm^2	$ML^{-1}T^{-2}$	Independent	Constant
8	Ds = Diameter of stem	mm	L	Independent	Variable
9	Wc = Actual width of cutter	mm	L	Independent	Variable
10	tc = Thickness of cutter	mm	L	Independent	Variable
11	Lc = Length of cutter	mm	L	Independent	Variable
12	Dd = Diameter of disc	mm	L	Independent	Variable
13	Dt = Thickness of disc	mm	L	Independent	Variable
14	Φc= cutting angle of cutter	Degree	--	Independent	Constant
15	N_c = Numbers of cutting blades	--	--	Independent	Constant

IV. FORMATION OF PI (Π) TERMS FOR INDEPENDENT VARIABLES

The Buckingham's Π- Theorem is used for the dimensional analysis of proposed machine after identifying the dependant and independent variables. The process of dimensional analysis is followed step by step as explained below:

The processing time, tp is function of Flywheel Energy (Ef), Angular speed of flywheel (ωf), Time required to speed up the flywheel (tf), Gear Ratio (G), Acceleration due to Gravity (g), Modulus of Elasticity of Material (Eb), Modulus of Elasticity of Cutter (Ec), Average diameter of stem (Ds), Actual width of cutter (Wc), Thickness of cutter (tc), Length of the cutter (Lc), Diameter of cutter disc (Dd), Thickness of cutter disc (Dt), Cutting Angle of Cutter (Φc), Number of cutting blades (Nc)

tp = f (Ef , ωf , tf, G, g, Em , Ec , Ds, Wc, tc, Lc, Dd, Dt, Φc Nc)

Or, f1 (Ef , ωf , tf, G, g, Em , Ec , Ds, Wc, tc, Lc, Dd, Dt, Φc Nc) = 0

g, Lb , Eb are considered as the repeating variables (i.e. m = 3)

Total no. of independent variables = n = 14

No. of Π terms = n – m = 14 - 3 = 11

Π_{D1} = f1 (Π1, Π2, Π3, Π4, Π5, Π6, Π7, Π8, Π9, Π10, Π11, Π12, Π13, Π14, Π15,) = 0

After following the procedure of dimensional analysis and after reduction of variable the following formulas for each independent Pi terms were found that are,

Table no 2, pi Terms Equations After Reduction of Veriable for Each Independent Pi Terms

pi terms	pi terms equations	Description
π_1	$\pi_1 = \frac{E_f}{D_s^3 E_c}$	The term related to energy of flywheel
π_2	$\pi_2 = \omega_f \sqrt{\frac{D_s}{g}}$	The term related to angular speed of flywheel
π_3	$\pi_3 = t_f \sqrt{\frac{g}{D_s}}$	The term related to time required to speed up the flywheel
π_4	$\pi_4 = G$	The term related to gear ratio
π_5	$\pi_5 = \frac{E_c}{E_b}$	The term related to elasticity of materials
π_6	$\pi_6 = \left(\frac{W_c t_c L_c D_d D_t}{D_s^5}\right)$	Machine's geometrical parameters
π_7	$\pi_7 = \varphi_c$	The term related to cutting angle of cutter
π_8	$\pi_8 = N_c$	Number of cutting blades

Likewise for each dependent Pi terms the pi terms were found that are,

Table no 3, pi Terms Equations for Each Dependent Pi Terms

pi terms	pi terms equations
π_{D1}	$\pi_{D1} = t_P \sqrt{\frac{g}{D_s}}$
π_{D2}	$\pi_{D2} = \frac{W_o}{D_s^2 E_c}$
π_{D3}	$\pi_{D3} = \frac{T_r}{D_s^3 E_c}$

So as we know, Π_{D1} = f1 (Π1, Π2, Π3, Π4, Π5, Π6, Π7, Π8,) = 0

Π_{D2} = f1 (Π1, Π2, Π3, Π4, Π5, Π6, Π7, Π8,) = 0

Π_{D3} = f1 (Π1, Π2, Π3, Π4, Π5, Π6, Π7, Π8,) = 0

V. FORMING MATHEMATICAL EQUATION FOR EACH DEPENDENT PI TERMS

- **For Processing Time (t_p)**

$$t_p\sqrt{\frac{g}{D_s}} = f_1\left\{\left(\frac{E_f}{D_s^3E_c}\right)\left(\omega_f\sqrt{\frac{D_s}{g}}\right)\left(t_f\sqrt{\frac{g}{D_s}}\right)(G)\left(\frac{E_m}{E_c}\right)\left(\frac{W_c}{D_s}\right)\left(\frac{t_c}{D_s}\right)\left(\frac{L_c}{D_s}\right)\left(\frac{D_d}{D_s}\right)\left(\frac{D_t}{D_s}\right)(\varphi_c)\,(N_c)\right\}$$

$$t_p\sqrt{\frac{g}{D_s}} = f_1\left\{\left(\frac{E_f}{D_s^3E_c}\right)\left(\omega_f\sqrt{\frac{D_s}{g}}\right)\left(t_f\sqrt{\frac{g}{D_s}}\right)(G)\left(\frac{E_c}{E_b}\right)\left(\frac{W_ct_cL_cD_dD_t}{L_b^5}\right)(\varphi_c)(N_c)\right\}$$

- **For Output weight of chips produced (Wo)**

$$\frac{W_o}{D_s^2E_c} = f_2\left\{\left(\frac{E_f}{D_s^3E_c}\right)\left(\omega_f\sqrt{\frac{D_s}{g}}\right)\left(t_f\sqrt{\frac{g}{D_s}}\right)(G)\left(\frac{E_m}{E_c}\right)\left(\frac{W_c}{D_s}\right)\left(\frac{t_c}{D_s}\right)\left(\frac{L_c}{D_s}\right)\left(\frac{D_d}{D_s}\right)\left(\frac{D_t}{D_s}\right)(\varphi_c)\,(N_c)\right\}$$

$$\frac{W_o}{D_s^2E_c} = f_2\left\{\left(\frac{E_f}{D_s^3E_c}\right)\left(\omega_f\sqrt{\frac{D_s}{g}}\right)\left(t_f\sqrt{\frac{g}{D_s}}\right)(G)\left(\frac{E_c}{E_b}\right)\left(\frac{W_ct_cL_cD_dD_t}{L_b^5}\right)(\varphi_c)(N_c)\right\}$$

- **For Average Resistive Torque (Tr)**

$$\frac{T_r}{D_s^3E_c} = f_2\left\{\left(\frac{E_f}{D_s^3E_c}\right)\left(\omega_f\sqrt{\frac{D_s}{g}}\right)\left(t_f\sqrt{\frac{g}{D_s}}\right)(G)\left(\frac{E_m}{E_c}\right)\left(\frac{W_c}{D_s}\right)\left(\frac{t_c}{D_s}\right)\left(\frac{L_c}{D_s}\right)\left(\frac{D_d}{D_s}\right)\left(\frac{D_t}{D_s}\right)(\varphi_c)\,(N_c)\right\}$$

$$\frac{T_r}{D_s^3E_c} = f_2\left\{\left(\frac{E_f}{D_s^3E_c}\right)\left(\omega_f\sqrt{\frac{D_s}{g}}\right)\left(t_f\sqrt{\frac{g}{D_s}}\right)(G)\left(\frac{E_c}{E_b}\right)\left(\frac{W_ct_cL_cD_dD_t}{L_b^5}\right)(\varphi_c)(N_c)\right\}$$

VI. DEVELOPING THE MODEL FOR DEPENDENT PI TERM

6.1 π_{D1} Processing Time, t_p

Generalized experimental models for predicting processing time for Pigeon Pea stalk chipping process by human powered flywheel motor has been established.

πD1 = k1 x (π1)a1 x (π2)b1 x (π3)c1 x (π4)d1 x (π5)e1 x (π6)f1 x (π7)g1 x (π8)h1

The values of exponential a1, b1, c1, d1, e1, f1, g1, h1 are established, considering exponential relationship between dependent pi term tp and Independent π terms π1, π2, π3, π4, π5, π6, π7, π8 independently taken one at a time, on the basic of data collected through classical experimentation. There are nine unknown terms in the above equation. These are curve fitting constant K1 and indices a1, b1, c1, d1, e1, f1, g1, h1. To get the values of these unknown we need minimum nine sets of values of (π1, π2, π3, π4, π5, π6, π7, π8). Taking log on the both sides of equation for πD1, to get eight unknown terms in the equations,

Log πD1 = log k1+ a1log π1+ b1log π2+ c1log π3 + d1log π4 + e1log π5 + f1log π6 + g1log π7 + h1log π8

Let, Z1= log πD1, K1 = log k1, A = log π1, B = log π2, C = log π3, D = log π4, E = log π5, F = log π6 G = log π7, H = log π8, Putting the values in equations the same can be written as

Z1 = K1+ a1 A + b1 B + c1 C + d1 D + e1 E + f1 F + g1G + h1H

This represents a regression hyper plane. To determine the regression hyper plane, determine a1, b1, c1, d1, e1, f1, g1 and h1in above equation so that,

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ΣZ1 = nK1 + a1*ΣA + b1*ΣB + c1*ΣC + d1* ΣD + e1*ΣE + f1*ΣF + g1*ΣG + h1*ΣH

ΣZ1*A = K1*ΣA +a1*ΣA*A + b1*ΣB*A + c1*ΣC*A + d1* ΣD*A + e1*ΣE*A+f1*ΣF*A + g1*ΣG*A + h1*ΣH*A

ΣZ1*B = K1*ΣB +a1*ΣA*B + b1*ΣB*B + c1*ΣC*B + d1* ΣD*B + e1*ΣE*B+f1*ΣF*B + g1*ΣG*B + h1*ΣH*B

ΣZ1*C = K1*ΣC +a1*ΣA*C+ b1*ΣB*C + c1*ΣC*C + d1* ΣD*C + e1*ΣE*C+f1*ΣF*C+ g1*ΣG*C + h1*ΣH*C

ΣZ1*D = K1*ΣD +a1*ΣA*D + b1*ΣB*D + c1*ΣC*D + d1* ΣD*D + e1*ΣE*D+f1*ΣF*D+g1*ΣG*D + h1*ΣH*D

ΣZ1*E = K1*ΣE +a1*ΣA*E + b1*ΣB*E + c1*ΣC*E + d1* ΣD*E + e1*ΣE*E+f1*ΣF*E + g1*ΣG*E + h1*ΣH*E

ΣZ1*F = K1*ΣF +a1*ΣA*F + b1*ΣB*F + c1*ΣC*F + d1* ΣD*F + e1*ΣE*F+f1*ΣF*F + g1*ΣG*F + h1*ΣH*F

ΣZ1*G = K1*ΣG +a1*ΣA*G + b1*ΣB*G + c1*ΣC*G +d1* ΣD*G +e1*ΣE*G+f1*ΣF*G+g1*ΣG*G + h1*ΣH*G

ΣZ1*H = K1*ΣH +a1*ΣA*G + b1*ΣB*G + c1*ΣC*G +d1* ΣD*G +e1*ΣE*G+f1*ΣF*G+g1*ΣG*G + h1*ΣH*H

The matrix method of solving these equations using 'MS - EXCEL' is given below.

W = 9 x 9 matrix of the multipliers of K1, a1, b1, c1, d1, e1, f1, g1 and h1

P1 = 9 x 1 matrix of the terms on L H S and

X1 = 9 x 1 matrix of solutions of values of K1, a1, b1, c1, d1, e1, f1 g1 and h1

Then, the matrix obtained is given by,

$$Z_1 \quad x \begin{bmatrix} 1 \\ A \\ B \\ C \\ D \\ E \\ F \\ G \\ H \end{bmatrix} = \begin{bmatrix} n & A & B & C & D & E & F & G \\ A & A^2 & BA & CA & DA & EA & FA & GA \\ B & AB & B^2 & CB & DB & EB & FB & GB \\ C & AC & BC & C^2 & DC & EC & FC & GC \\ D & AD & BD & CD & D^2 & ED & FD & GD \\ E & AE & BE & CE & DE & E^2 & FE & GE \\ F & AF & BF & CF & DF & EF & F^2 & GF \\ G & AG & BG & CG & DG & EG & FG & G^2 \\ H & AH & BH & CH & DH & EH & FH & H^2 \end{bmatrix} \quad x \begin{bmatrix} K_1 \\ a_1 \\ b_1 \\ c_1 \\ d_1 \\ e_1 \\ f_1 \\ g_1 \\ h_1 \end{bmatrix}$$

246.25		72.0	-310.5	6.4	230.6	-33.2	-127.1	306.7	-8.8	34.4		K_1
-1058.1		-310.5	1357.7	-28.2	-990.6	143.4	548.3	-1298.1	37.8	-148.2		a_1
22.00		6.4	-28.2	1.9	20.5	-2.9	-11.2	23.0	-0.8	3.0		b_1
789.45	=	230.6	-990.6	20.5	739.7	-106.8	-407.1	986.7	-28.2	110.0		c_1
-113.69		-33.2	143.4	-2.9	-106.8	16.4	58.7	-141.6	4.1	-15.9	X	d_1
-434.84		-127.1	548.3	-11.2	-407.1	58.7	224.5	-541.6	15.5	-60.7		e_1
1053.30		306.7	-1298.1	23.0	986.7	-141.6	-541.6	1347.5	-37.4	146.3		f_1
-29.94		-8.8	37.8	-0.8	-28.2	4.1	15.5	-37.4	2.2	-4.2		g_1
117.49		34.4	-148.2	3.0	110.0	-15.9	-60.7	146.3	-4.2	16.4		h_1

After solving above matrix value of K1 and indices are found to be for a1, b1, c1, d1, e1, f1, g1, h1 are as follows

K1	a_1	b_1	c_1	d_1	e_1	f_1	g_1	h_1
2.305	**0.104**	**0.537**	**-0.041**	**-0.052**	**-0.125**	**0.099**	**0.088**	**2.000**

But K_1 is log value so to convert into normal value taking antilog of K_1

Antilog **(2.305) = 201.8**

Hence the model for dependent term π_{D1} i.e. Processing Time, t_p is

$\pi_{D1} = k_1 \times (\pi_1)^{a1} \times (\pi_2)^{b1} \times (\pi_3)^{c1} \times (\pi_4)^{d1} \times (\pi_5)^{e1} \times (\pi_6)^{f1} \times (\pi_7)^{g1} \times (\pi_8)^{h1}$

$$t_p\sqrt{\frac{g}{D_s}} = K_1\left\{\left(\frac{E_f}{D_s^3 E_c}\right)^{a1}\left(\omega_f\sqrt{\frac{D_s}{g}}\right)^{b1}\left(t_f\sqrt{\frac{g}{D_s}}\right)^{c1}(G)^{d1}\left(\frac{E_m}{E_c}\right)^{e1}\left(\frac{W_c t_c L_c D_d D_t}{D_s^5}\right)^{f1}(\varphi_c)^{g1}(N_c)^{h1}\right\}$$

$$t_p = K_1\sqrt{\frac{D_s}{g}}\left\{\left(\frac{E_f}{D_s^3 E_c}\right)^{a1}\left(\omega_f\sqrt{\frac{D_s}{g}}\right)^{b1}\left(t_f\sqrt{\frac{g}{D_s}}\right)^{c1}(G)^{d1}\left(\frac{E_m}{E_c}\right)^{e1}\left(\frac{W_c t_c L_c D_d D_t}{D_s^5}\right)^{f1}(\varphi_c)^{g1}(N_c)^{h1}\right\}$$

$$t_p = 201.8\sqrt{\frac{D_s}{g}}\left\{\left(\frac{E_f}{D_s^3 E_c}\right)^{0.104}\left(\omega_f\sqrt{\frac{D_s}{g}}\right)^{0.537}\left(t_f\sqrt{\frac{g}{D_s}}\right)^{-0.041}(G)^{-0.052}\left(\frac{E_m}{E_c}\right)^{-0.125}\left(\frac{W_c t_c L_c D_d D_t}{D_s^5}\right)^{0.099}(\varphi_c)^{0.088}(N_c)^{2.000}\right\}$$

6.2 $\pi_{D2,}$ Output Weight of Chips Produced

$\pi D2 = f(\pi 1, \pi 2, \pi 3, \pi 4, \pi 5, \pi 6, \pi 7, \pi 8)$

$\pi D2 = k2 \times (\pi 1)a2 \times (\pi 2)b2 \times (\pi 3)c2 \times (\pi 4)d2 \times (\pi 5)e2 \times (\pi 6)f2 \times (\pi 7)g2 \times (\pi 8)h2$

$\pi D2 = k2 \times (\pi 1)a2 \times (\pi 2)b2 \times (\pi 3)c2 \times (\pi 4)d2 \times (\pi 5)e2 \times (\pi 6)f2 \times (\pi 7)g2 \times (\pi 8)h2$

Taking log on the both sides of equation for $\pi D2$, to get eight unknown terms in the equations,

Log $\pi D21$ = log k2+ a2log $\pi 1$+ b2log $\pi 2$+ c2log $\pi 3$ + d2log $\pi 4$ + e2log $\pi 5$ + f2log $\pi 6$ + g2log $\pi 7$ + h2log $\pi 8$

By the same steps, the matrix obtained is given by,

$$\begin{vmatrix} -466.91 \\ 2025.33 \\ -41.98 \\ -1492.8 \\ 215.51 \\ 824.47 \\ -1972.7 \\ 56.97 \\ -222.77 \end{vmatrix} = \begin{vmatrix} 72.0 & -310.5 & 6.4 & 230.6 & -33.2 & -127.1 & 306.7 & -8.8 & 34.4 \\ -310.5 & 1357.7 & -28.2 & -990.6 & 143.4 & 548.3 & -1298.1 & 37.8 & -148. \\ 6.4 & -28.2 & 1.9 & 20.5 & -2.9 & -11.2 & 23.0 & -0.8 & 3.0 \\ 230.6 & -990.6 & 20.5 & 739.7 & -106.8 & -407.1 & 986.7 & -28.2 & 110.0 \\ -33.2 & 143.4 & -2.9 & -106.8 & 16.4 & 58.7 & -141.6 & 4.1 & -15.9 \\ -127.1 & 548.3 & -11.2 & -407.1 & 58.7 & 224.5 & -541.6 & 15.5 & -60.7 \\ 306.7 & -1298.1 & 23.0 & 986.7 & -141.6 & -541.6 & 1347.5 & -37.4 & 146.3 \\ -8.8 & 37.8 & -0.8 & -28.2 & 4.1 & 15.5 & -37.4 & 2.2 & -4.2 \\ 34.4 & -148.2 & 3.0 & 110.0 & -15.9 & -60.7 & 146.3 & -4.2 & 16.4 \end{vmatrix} \times \begin{vmatrix} K_2 \\ a_2 \\ b_2 \\ c_2 \\ d_2 \\ e_2 \\ f_2 \\ g_2 \\ h_2 \end{vmatrix}$$

After solving above matrix value of K2 and indices are found to be for a2, b2, c2, d2, e2, f2, g2, h2 are as follows

K2	a_2	b_2	c_2	d_2	e_2	f_2	g_2	h_2
-7.602	**-0.007**	**1.055**	**-0.002**	**0.013**	**-1.375**	**0.510**	**0.022**	**-7.500**

But K2 is log value so to convert into normal value, taking antilog of K2

Antilog **(-7.602) = 2.50E-08**

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Hence the model for dependent term πD2

πD2 = k1 x (π1)a2 x (π2)b2 x (π3)c2 x (π4)d2 x (π5)e2 x (π6)f2 x (π7)g2 x (π8)h2

$$\left(\frac{W_o}{D_s^2E_c}\right) = f\left\{\left(\frac{E_f}{D_s^3E_c}\right)\left(\omega_f\sqrt{\frac{D_s}{g}}\right)\left(t_f\sqrt{\frac{g}{D_s}}\right)(G)\left(\frac{E_m}{E_c}\right)\left(\frac{W_ct_cL_cD_dD_t}{D_s^5}\right)(\varphi_c)(N_c)\right\}$$

$$W_o = K_2(D_s^2E_c)\left\{\left(\frac{E_f}{D_s^3E_c}\right)^{a2}\left(\omega_f\sqrt{\frac{D_s}{g}}\right)^{b2}\left(t_f\sqrt{\frac{g}{D_s}}\right)^{c2}(G)^{d2}\left(\frac{E_m}{E_c}\right)^{e2}\left(\frac{W_ct_cL_cD_dD_t}{D_s^5}\right)^{f2}(\varphi_c)^{g2}(N_c)^{h2}\right\}$$

$$W_o = 2.50E - 08\,(D_s^2E_c)\left\{\left(\frac{E_f}{D_s^3E_c}\right)^{-0.007}\left(\omega_f\sqrt{\frac{D_s}{g}}\right)^{1.055}\left(t_f\sqrt{\frac{g}{D_s}}\right)^{-0.002}(G)^{0.013}\left(\frac{E_m}{E_c}\right)^{-1.375}\left(\frac{W_ct_cL_cD_dD_t}{D_s^5}\right)^{0.510}(\varphi_c)^{0.022}(N_c)^{-7.500}\right\}$$

6.3 π_{D3}, Average Resistive torque, Tr_{avg}

πD_3 = f (π1, π2, π3, π4, π5, π6, π7, π8)

πD_3= k_3 x (π1)a3 x (π2)b3 x (π3)c3x (π4)d3 x (π5)e3 x (π6)f3x (π7)g3 x (π8)h3

πD_3= k_3 x (π1)a3 x (π2)b3 x (π3)c3x (π4)d3 x (π5)e3 x (π6)f3x (π7)g3 x (π8)h3

Taking log on the both sides of equation for πD3, to get eight unknown terms in the equations,

Log πD3 = log k3+ a3log π1+ b3log π2+ c3log π3 + d3log π4 + e3log π5 + f3log π6 + g3log π7 + h3log π8

By the same steps, the matrix obtained is given by,

-241.03		72.0	-310.5	6.4	230.6	-33.2	-127.1	306.7	-8.8	34.4		K_3
1054.47		-310.5	1357.7	-28.2	-990.6	143.4	548.3	-1298.1	37.8	-148.		a_3
-23.62		6.4	-28.2	1.9	20.5	-2.9	-11.2	23.0	-0.8	3.0		b_3
-768.54	=	230.6	-990.6	20.5	739.7	-106.8	-407.1	986.7	-28.2	110.0		c_3
109.53		-33.2	143.4	-2.9	-106.8	16.4	58.7	-141.6	4.1	-15.9	X	d_3
425.62		-127.1	548.3	-11.2	-407.1	58.7	224.5	-541.6	15.5	-60.7		e_3
-1002.4		306.7	-1298.1	23.0	986.7	-141.6	-541.6	1347.5	-37.4	146.3		f_3
29.39		-8.8	37.8	-0.8	-28.2	4.1	15.5	-37.4	2.2	-4.2		g_3
-115.00		34.4	-148.2	3.0	110.0	-15.9	-60.7	146.3	-4.2	16.4		h_3

After solving above matrix value of K3 and indices are found to be for a3, b3, c3, d3, e3, f3, g3, h3 are as follows

K3	**a_3**	**b_3**	**c_3**	**d_3**	**e_3**	**f_3**	**g_3**	**h_3**
-6.710	**-0.107**	**0.250**	**0.179**	**-1.491**	**-1.313**	**0.669**	**-0.002**	**-7.500**

But K_3 is log value so to convert into normal value, taking antilog of K_3

Antilog **(-6.710) = 1.95E-07**

Hence the model for dependent term π_{D3}

$\pi_{D3} = k_1 \text{ x } (\pi_1)^{a3} \text{ x } (\pi_2)^{b3} \text{ x } (\pi_3)^{c3} \text{ x } (\pi_4)^{d3} \text{ x } (\pi_5)^{e3} \text{ x } (\pi_6)^{f3} \text{ x } (\pi_7)^{g3} \text{ x } (\pi_8)^{h3}$

$$\left(\frac{T_r}{D_s^3 E_c}\right) = K_3 \left\{ \left(\frac{E_f}{D_s^3 E_c}\right)^{a3} \left(\omega_f \sqrt{\frac{D_s}{g}}\right)^{b3} \left(t_f \sqrt{\frac{g}{D_s}}\right)^{c3} (G)^{d3} \left(\frac{E_m}{E_c}\right)^{e3} \left(\frac{W_c t_c L_c D_d D_t}{D_s^5}\right)^{f3} (\varphi_c)^{g3} (N_c)^{h3} \right\}$$

$$T_r = K_3 (D_s^3 E_c) \left\{ \left(\frac{E_f}{D_s^3 E_c}\right)^{a3} \left(\omega_f \sqrt{\frac{D_s}{g}}\right)^{b3} \left(t_f \sqrt{\frac{g}{D_s}}\right)^{c3} (G)^{d3} \left(\frac{E_m}{E_c}\right)^{e3} \left(\frac{W_c t_c L_c D_d D_t}{D_s^5}\right)^{f3} (\varphi_c)^{g3} (N_c)^{h3} \right\}$$

$$\boldsymbol{T_r} = 1.95\mathrm{E} - 07 \left(L_b^3 E_b\right) \left\{ \left(\frac{E_f}{D_s^3 E_c}\right)^{-0.107} \left(\omega_f \sqrt{\frac{D_s}{g}}\right)^{0.250} \left(t_f \sqrt{\frac{g}{D_s}}\right)^{0.179} (G)^{-1.491} \left(\frac{E_m}{E_c}\right)^{-1.313} \left(\frac{W_c t_c L_c D_d D_t}{D_s^5}\right)^{0.669} (\varphi_c)^{-0.002} (N_c)^{-7.500} \right\}$$

VII. CONCLUSION

1. Thus the experimental data based model are established for formulation of the mathematical model in reduced or compact mode in order to make the complete experimentation process less time taking having generation of optimum data. The dimensionless π terms have provided the idea about combined effect of process parameters in that π terms. A simple change in one process parameter in the group helps the manufacturer to maintain the required tp, Wo and Tr values so that the productivity is increased.
2. The mathematical models developed with dimensional analysis for different sizes of wood chips can be effectively utilized for chipping operations.
3. The computed selection of wood chipping process parameters by dimensional analysis provides effective guidelines to the manufacturing engineers so that they can minimize tp, Wo and Tr for higher performances.
4. The models have been formulated mathematically for the Indian conditions. The comparison of values of dependent term obtained from experimental data, mathematical model, it seems that the mathematical models can be successfully used for the computation of dependent terms for a given set of independent terms. Indian industries can use the data for calculation cutting forces and power estimation for wood chipping machines.

REFERENCES

[1] Moghe S.D., “Formulation of generalized experimental model for determination of optimum cranking arrangement of a cycle rickshaw”, proceeding of 10th IFToMM world congress on Theory of machine and mechanism, Union of Oulu- Finland, June 20-24, 1999.

[2] Modak J. P., “Spealized course on Research Methodology in Engineering”, Priyadarshini college of Engineering, Nagpur (India).

[3] Modak, J. P. and Bapat, A. R., “Formulation of Generalized Experimental Model for a Manually Driven Flywheel Motor and its Optimization”, Applied Ergonomics, U.K., Vol. 25, No. 2, pp 119-122, 1994.

[4] Modak, J. P. and Bapat, A. R, “ Manually driven flywheel motor operates wood turning process” Contemporary Ergonomics, Proc. Ergonomics Society Annual Convention 13-16 April, Edinburgh, Scotland, pp 352-357, 1993

[5] Bapat, A. R., "Design of Experimentation for Establishing Generalized Experimental Model for a Manually Driven Flywheel Motor", Proceedings of International Conference, Modeling and Simulation, New Delhi, Oct. 1987, Vol. 8, pp 127-140.

[6] Modak, J. P. and Katpatal A.A., "Design of Manually Energized Centrifugal Drum Type Algae Formation Unit"Proceedings International AMSE Conference on System, Analysis, Control and Design, Layon (France), Vol. 3, 4-6 July 1994, pp 227-232.

[7] C.N. Sakhale et al, "Design and development of a comprehensive bamboo processing machine and estimation of power required for each processing operation" International J. of Engg. Research & Indu. Appls. (IJERIA), Vol.3, No. IV, November 2010, pp. 103-127.

[8] H. Sqenck .Jr, ``Theory of engineering experimentation`` Mc-GrawHill, inc. Newyork

[9] Zakiuddin Syed Kazi, Jayant P. Modak, "Design and Development of the Human Energized Chaff Cutter", New York Science Journal, 2010, pp. 104 – 108.