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Formulation of Experimental Data Base Model of Processing Time for Human Powered Food Grain Crusher

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Abstract –*Powdered food grains are a base of almost all foods in India. In ancient times, food grains are ground with the help of hand grain crushers. Today the electric motor driven grain crushers are used. But today there is a huge scarcity of electricity almost everywhere in India which results in six to twelve hours load shedding. In rural areas the load shedding is done daily from ten to twelve hours which badly affects their daily needs requiring electricity such as food grain crushing, water supply etc. To overcome this, we can replace the electric motor driven process units by manually driven process units such as food grain crusher driven by human powered flywheel motor [1]* i.e. manually driven food grain crusher. Also we all know that hand muscles are weaker than the leg muscle [24] i.e. we can operate the food grain crusher without fatigue and smoothly for a longer period if we replace hand operated food grain crusher by pedal operated food grain crusher.*

Key Words: Process unit, food grain crusher, pedal driven, human powered flywheel motor, ANN

1.INTRODUCTION

The Human powered Flywheel motor comprises of three sub systems namely (i) Energy supply unit(peddling mechanism to supply power or to store energy in flywheel) (ii)Appropriate clutch and transmission and (iii) a process unit.

The complete unit consists of a bicycle mechanism, an appropriate clutch and transmission system and a process unit which could be any process device needing power up to 7 hp. Here it is food grain crusher.

Referring Fig 1.1 The rider sits on the seat and paddles the bicycle mechanism while the clutch is in dis-engaged position. Thus the load on the legs of the rider is only the inertia load of the flywheel. The Flywheel is accelerated to the speed of 800 rpm in minutes time by a young rider of the age group of 20 to 25 physically fit of height about 165 cm. The Flywheel size is 1m rim diameter, 10cm rim width and 2cm rim thickness. Such a Flywheel when energized to the speed of 800 rpm, it stores energy to the extent of 3200 kgf-m. At the end of 1 minute, speed of 800 rpm is reached and so much of energy is stored in a Flywheel. Afterwards the peddling is stopped, clutch is engaged and such a stored energy in the flywheel is communicated to the process unit through the clutch. Obviously the clutch is subjected to sever shock on account of instantaneous momentum transfer. This is so because as the clutches engaged, the Flywheel is subjected to the process load and the process unit consumes shaft energy of the Flywheel. After the clutch engagement, the energy stored in a Flywheel gets exhausted in 5 to 15 seconds for application tried so far (ref [1] to [7],[10],[21]). The capacity of such a system is in the range of 2.5 to 8.5 Hp. The functional feasibility and economic viability of this system has also been confirmed ([1] to [7],[10],[21]).

Schematic arrangement of the complete unit:

1-Chain Sprocket 2-Pedal 3-Chain 4-Freewheel 5,6-Bearings for bicycle side 7-Gear-I 8-Bearing 9-Tachogenerator for flywheel shaft 10-Pinion-I 11-Bearing for flywheel shaft 12-Flywheel 13-Bearing for flywheel 14-Two jaw clutch 15,15-Bearing of intermediate shaft 17-Pinion II 18-Gear II 19,20-Bearing for process unit shaft 21-Coupling 22-Food Grain Crusher

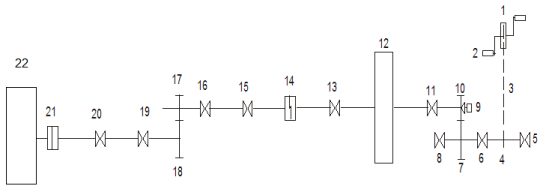

Fig -1: Schematic of Human Powered Flywheel Motor

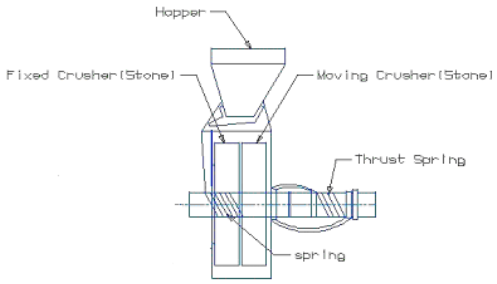

Fig -2: Food Grain Crusher (Process unit)

2. BACKGROUND OF THE PRESENT RESEARCH

Environmental pollution compelled human beings to think of renewable energy resources. In view, this vast research is going on in the field of harnessing human power. R.J. Fuller [21]has argued in his paper about animal power and human power as renewable energy sources. He also argues that human and animal power has significant contribution

compared to wind and hydropower in renewable energy sources.

Cori Denison [19] patented human powered device with removable flywheel power unit. As per this patent, the flywheel power unit can be inserted in to desired process unit to power the process.

Almost since 1978, Researcher J. P. Modak and his associates are working on Human powered flywheel motor [1 to 14]. The Human powered Flywheel Motor comprises of three sub system namely (i) Energy supply unit (Pedaling mechanism to supply power or to store energy in a Flywheel), (ii) Appropriate clutch and transmission and (iii) a process unit. (in this case Food Grain Crusher). The complete unit comprises a bicycle mechanism, appropriate clutch and transmission and process unit could be any process device needing power up to 7 Hp.

The concept is applied in past so far for keyed bricks, wood turning, algae formation machine, fodder chopper, oilseed presser [7,10,11,12,13]. etc. and can be looked upon models of those systems as design data for designing such systems.

3. OBJECTIVES OF PROPOSED WORK

The energy sources of such systems are considered as one form of non- conventional energy source. The importance of this source is for the remote and interior area for energizing process unit in the range up to 7 Hp. For this range, large number of process machines is required to be energized [14].

For small farmers, it is necessary to adopt this concept for small agricultural implements. Accordingly it has been adopted for several processes such as keyed bricks, wood turning, algae formation machine, fodder chopper, oilseed presser [7,10,11,12,13]. The suggestions from food grain crusher operators, working in villages and remote areas, to develop such a food grain crusher which will be cheap and independent of conventional energy sources, motivate us. If such a Food Grain Crusher is developed it will be of great help to poor people / people in villages [1], firstly because it does not need conventional energy and it may generate work for one of the family member.

A large area around the vicinity of college is a rural area and almost all rural areas in India are affected by load shedding which greatly hampers the daily needs, growth and development of these rural areas. If the institute focuses its research work on replacing the electricity driven process units by human powered flywheel motor driven process units, then it will be of great help to such rural areas for the overall growth and development. Also it can generate fund for the institute for its self-dependence through such research activities.

The basic objective of this work is to generate design data for food grain crusher using human powered flywheel motor by the way of performing extensive experimentation by varying independent variables over widest possible range and gathering the response data generated. Finally the models can be formed as per the data observations obtained from the classical approach of experimentation put forth by H. Schank Jr [25].

4. EXPERIMENTAL SET UP

The experimental setup is as shown in Fig -3. In human energized food grain crusher, the objective of the experiment is to collect information with the help of experimentation for the formulation of mathematical model of food grain crusher. After the engagement of the clutch, the processing Time (TP) is measured with the help of an electronic kit.

Fig -3: An Experimental Set Up Photo

5. EXPERIMENTATION METHODOLOGY

Here the classical approach of design of experimentation has been applied for the model formulation as proposed by H. Schank Jr.[26].

5.1 Design of Experimentation

Series of experiments were conducted to study the effect on processing time for human energized food grain crusher. This experimentation has been carried out to investigate the processing time considering various parameters of food grains and processing machine i. e. process unit. During experimentation, wheat and sorghum were used for the data collection and investigation. Also the various geometrical parameters of the process unit are varied during experimentation. This collected data i.e. observations then analyzed and processed for the formulation of the model.

5.2 Experimental Approach

The working phenomenon of food grain crusher is a process which is highly complex because of continuous variation of speed of the process unit input shaft, understanding such a phenomenon cannot be logic based. Hence it is necessary to adopt application of methodology of experimentation to such a complex process for formulating experimental data based model. Hence Theory of

Experimentation by H. Schenk Jr.[26]. is proposed to be applied.

Brief Methodology of Theory of Experimentation

1. Identification of variables affecting the phenomenon.

2. Reduction of variables by dimensional analysis

3. Test plan: consist of determination of test envelope, test points, test sequence and plan of experimentation.

4. Experimental set up design

5. Fabrication of experimental set up

6. Selecting appropriate instrumentation

7. Execution of experimental plan

8. Test data checking, rejection of outliers and data purification

9. Formulation of experimental data based models.

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5.3 Identification of Variables Affecting the Phenomenon

In this the various independent variables affecting the phenomenon have been identified. Processing time is the dependant variable. Those are listed in the table below.

Table -1: Identification of Variables

SN	Variables	Symbol	Dimensions	Nature of Variables
1	Average size of food grains	a	$[M^0L^1T^0]$	Independent
2	Density of food grains	ρ_G	$[M^1L^{-3}T^0]$	Independent
3	Hardness of food grains	h_G	$[M^1L^{-1}T^{-2}]$	Independent
4	Mass of input food grains	m	$[M^1L^0T^0]$	Independent
5	Diameter of stone	D	$[M^0L^1T^0]$	Independent
6	Hardness of stone	hs	$[M^0L^0T^0]$	Independent
7	Distance between the rotating and fixed stone	d	$[M^0L^1T^0]$	Independent
8	Roughness of stone	r_F	$[M^0L^1T^0]$	Independent
9	Density of stone	ρ_S	$[M^1L^{-3}T^0]$	Independent
10	Moment of Inertia of rotating stone	I_S	$[M^1L^2T^0]$	Independent
11	Gear ratio	G	$[M^0L^0T^0]$	Independent
12	Moment of Inertia of flywheel	I_F	$[M^1L^2T^0]$	Independent
13	Acceleration due to gravity	g	$[M^0L^1T^{-2}]$	Independent
14	Angular speed of the flywheel	w	$[M^0L^0T^{-1}]$	Independent
15	Processing time	T_P	$[M^0L^0T^1]$	Dependant

5.4 Dimensional Analysis

The dimensional equation for a phenomenon reduces the number of independent variables in the experiments. This is done by applying Buckingham's π theorem. By applying this method eleven Pi terms are formed. Further to reduce the coplexity and to obtain the simplicity in the behaviour of the phenomenon, the Pi terms of independent variables are reduced by reduction of variables method as suggested by Schenk Jr.[26]. The Pi terms related to the independent variables are reduced to form a single new Pi term. In all total four Pi terms are formed, the first Pi term is the term related to food grain parameters, the second Pi term is the term related to Process Unit parameters, the third Pi term is the term related to gear ratio, and the fourth Pi term is the term related to energy of the flywheel.

Table -2: Independent Pi Terms

Independent Pi Terms		
Pi terms	**Pi terms equations**	**Description**
π_1	$\pi_1 = \frac{a\, h_G D}{mg}$	The term related to food grain parameters
π_2	$\pi_2 = \frac{h_S\, d\, r_F\, \rho_S D^3}{I_S}$	The term related to geometrical parameters of Process Unit
π_3	$\pi_3 = G$	The term related to gear ratio
π_4	$\pi_4 = \frac{I_F\, w}{\rho_G D^{4.5} g^{0.5}}$	The term related to energy of the flywheel

Table -3: Dependent Pi Terms

Dependent Pi Term		
Pi terms	**Pi terms equations**	**Description**
Π_{D1}	$\pi_{D1} = T_P\sqrt{\frac{g}{D}}$	Pi Term related to Processing Time

5.5 Test Planning

It comprises of deciding the test envelope, test points, test sequence and experimentation plan for the deduced set of dimensional equation.

5.6 Model Formulation

It is necessary to correlate the various independent and dependent terms involved in this very complex phenomenon. This correlation is nothing but a mathematical model for the processing time T_P. The mathematical model for processing time is as given below:

$$T_p\sqrt{\frac{g}{D}} = f_1\left\{\left(\frac{a\,h_C\,D}{m\,g}\right)\left(\frac{h_S\,d\;r_F\,\rho_S\,D^3}{I_S}\right)(G)\left(\frac{I_F\,w}{\rho_C\,D^{4.5}\,g^{0.5}}\right)\right\}$$

For wheat,

$$\Pi_{D1} = T_p\sqrt{\frac{g}{D}} =$$

$$4.04762 \times 10^{-23}\left(\frac{a\,h_C\,D}{mg}\right)^{6.1886}\left(\frac{h_S\,d\;r_F\,\rho_S\,D^3}{I_S}\right)^{0.1012}(G)^{-0.8788}\left(\frac{I_F\,w}{\rho_C\,D^{4.5}\,g^{0.5}}\right)^{1.0788}$$

For sorghum,

$$\Pi_{D1} = T_p\sqrt{\frac{g}{D}} =$$

$$9.58517 \times 10^{-18}\left(\frac{a\,h_C\,D}{mg}\right)^{6.7016}\left(\frac{h_S\,d\;r_F\,\rho_S\,D^3}{I_S}\right)^{0.1097}(G)^{-0.9213}\left(\frac{I_F\,w}{\rho_C\,D^{4.5}\,g^{0.5}}\right)^{1.1864}$$

6. MODEL VALIDATION

The observed data from the experimentation is separated into two parts viz. causes i.e. input data or the data of independent pi terms and the effects i.e. output data or the data of dependent pi terms. The input data and output data is imported to the software respectively.

This network is then trained using the training data. The computation errors in the actual and target data are computed and then the network is simulated.

After simulating the ANN, it is found that experimentally observed values are very close and in good agreement with the ANN predicted values validating the model formed.

The ANN result validates the mathematical model formed from the experimentation results as the percentage error is very less. Here the higher value of R2 for wheat is 0.968 while the value of R2 for sorghum is 0.985 as indicated in the graph of PiD1 Vs. Predicted value with ANN for wheat and sorghum both. Also the sum of squares error and relative error for both wheat and sorghum is very less as given in Table 4 and 5 respe. Thus promising the best results from ANN.

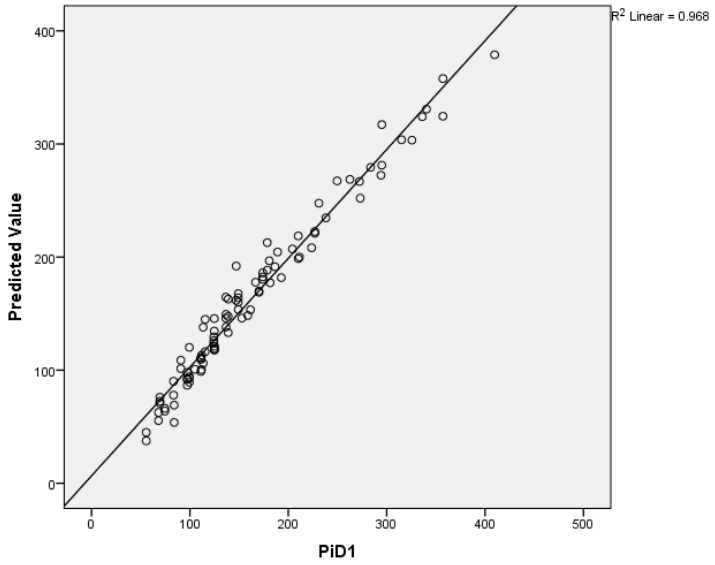

Fig -4: Graph of PiD1 Vs Predicted value with ANN for wheat

Table -4: Model Summary of PiD1 ANN for wheat

Model Summary		
Training	Sum of Squares Error	1.083
	Relative Error	.034
	Stopping Rule Used	1 consecutive step(s) with no decrease in error[a]
	Training Time	0:00:00.11
Testing	Sum of Squares Error	.289
	Relative Error	.026
Dependent Variable: PiD1		
a. Error computations are based on the testing sample.		

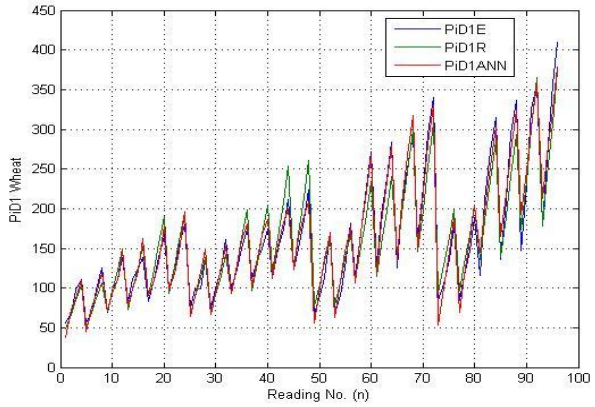

Fig -5: Comparison graph of Experimental, Regression and ANN for PiD1 of Wheat

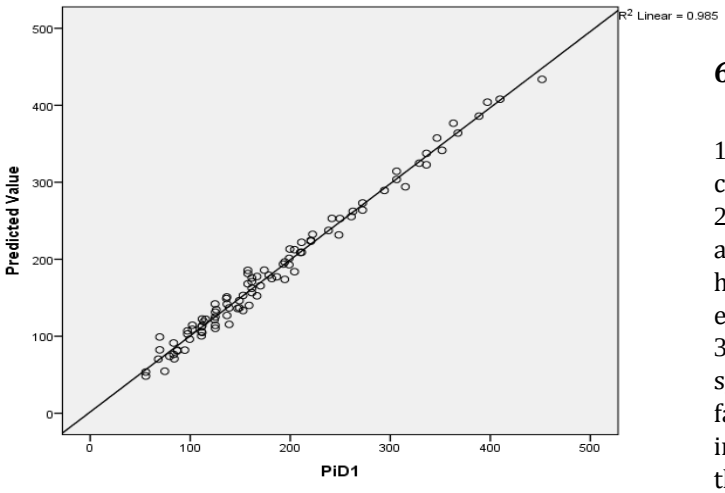

Fig -6: Graph of PiD1 Vs Predicted value with ANN for sorghum

Table -5: Model Summary of PiD1 ANN for sorghum

Model Summary		
Training	Sum of Squares Error	.373
	Relative Error	.013
	Stopping Rule Used	1 consecutive step(s) with no decrease in error[a]
	Training Time	0:00:00.05
Testing	Sum of Squares Error	.312
	Relative Error	.018
Dependent Variable: PiD1		
a. Error computations are based on the testing sample.		

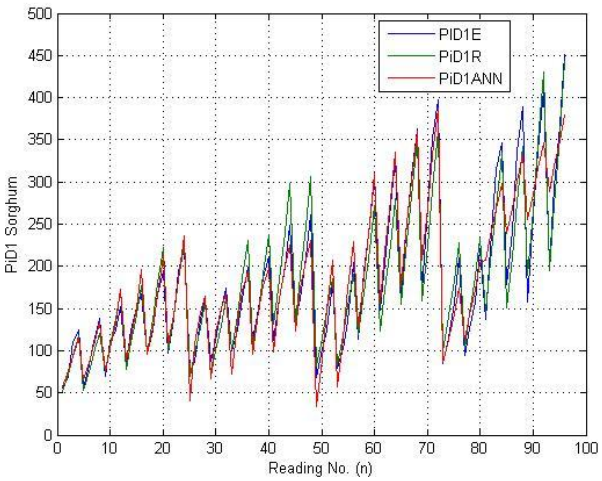

Fig -7: Comparison graph of Experimental, Regression and ANN for PiD1 of sorghum

6. CONCLUSION

1. The newly designed food grain crusher will work on non-conventional energy source.
2. In countries like India where ample human power is available, such human powered man machine systems will help in a great extend to improve the economic condition and employability of such countries in backward or remote areas .
3. Apart from use of such human powered man machine systems, those systems can be used for preparing poultry farm food which makes poultry farms in rural areas independent and such cheap poultry farm food will increase their profit margin.
4. Those models will work as a design data for such type of man machine systems.

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