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FORMULATION OF DATA BASED ANN MODEL FOR THE HUMAN POWERED FODDER - CHOPPER

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ABSTRACT

The paper presents to formulate an experimental data based ANN model for a Human Powered Fodder Chopper. The authors in their research paper published earlier have suggested the design of the experimentation for the formulation of such model. The experimentation has been carried out on a Fodder Chopper energized by human power. Mathematical models have been formulated, validated and optimized as per the suggested procedure. In this paper the ANN model is formulated to generate the correct values of the output parameters corresponding to the various values of the input parameters. The regression coefficient between the observed values and the values of the response variables computed by the ANN justifies this as best fit model. The developed ANN can now be used to select the best values of the various independent features for the designed chaff cutter to match the features of the machine operator performing the chaff cutting task so as to maximize the productivity and minimize torque, cutting time. Thus the entrepreneur selecting the best possible combinations of the input parameters by using this ANN can now improve the productivity of an experimental setup.

Keywords: *Human Powered, Flywheel Motor, Spiral jaw Clutch, Fodder Cutter, Models, Optimization, ANN Simulation.*

1. INTRODUCTION

The theory of experimentation as suggested by Hilbert [1] is a good approach of representing the response of any phenomenon in terms of proper interaction of various inputs of the phenomenon. This approach finally establishes an experimental data based model for any phenomenon. As suggested in this article the experimentation has been carried out and the models are formulated. The concept of least-square multiple regression curves as suggested by Spiegel [2] has been used to develop the models (herein after referred as mathematical model). An entrepreneur arranging optimized inputs so as to get targeted responses. This objective is only achievable by formulation of such models. An entrepreneur of an industry is always ultimately interested in arranging optimized inputs so as to get targeted responses. This objective is only achievable by formulation of such models. Once models are formulated they are optimized using the optimization technique. The optimum conditions, which the independent variables should satisfy for maximum productivity, have been deduced.

2. EXPERIMENTAL APPROACH

In the Fodder Chopping operation energized by human power under consideration no known logic can be applied correlating the various dependent and independent parameters of the system. Murrel [3] comments that whatever quantitative relationships are available for a specific population are of statistical nature. Hence one is left with only alternative of formulating experimental data based models to be more specific field data based models.

Normally the approach adopted for formulating generalized experimental model suggested by Hilbert for any complex physical phenomenon involves following steps.

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www.jatit.org

2A. IDENTIFICATION OF THE DEPENDENT AND INDEPENDENT PARAMETERS OF THE SYSTEM

The process variables for human powered chaff cutter was identified and are as tabulated in Table: 1. Dimensional analysis was carried out to established dimensional equations, exhibiting relationships between dependent π terms and independent π terms using Buckingham π theorem. [4].

Fig 1: Chaff Cutter Blade

2.B. REDUCTION OF THE VARIABLES

It can be seen that there are large number of variables involved in this man- machine system. The technique of dimensional analysis has been used to reduce the number of variables in to few dimensionless pi terms.
The independent and the dependent pi terms as formulated are shown in the table I. Thus there are thirteen independent pi terms and three dependent pi terms in this experimentation. Applying Buckingham π theorem the dimensional equations for resistive torque, number of cuts, process time are formulated as under.

RESISTIVE TORQUE:

$Tc = f[(d/D), n, (D^4/gI)E, (W_b/D), (t_b/D), \alpha, (\sqrt{(D/g)}\,\omega), G]\ \sqrt{(g/D)}\ t_c](D/gI)$

$Tc = f[(dW_b t_b/D^3), (D^4/gI)E, \alpha, G, n, (\sqrt{(D/g)}\,\omega)\ \sqrt{(g/D)}\ t_c]$ --- (1)

NUMBER OF CUTS:

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

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

PROCESS TIME FOR CUTTING (T_P):

$t_p = f[(dW_b t_b/D^3), (D^4/gI)E, (\sqrt{(D/g)}\,\omega), G, \alpha, n]$

$\sqrt{(g/D)}\ t_p = f[(dW_b t_b/D^3), (D^4/gI)E, (\sqrt{(D/g)}\,\omega), G, \alpha, n]\ \sqrt{(g/D)}\ t_c]$ ---- (3)

In equations 1,2and 3, f stands for "function of".

2. C TEST PLANNING

This comprises of deciding test envelope, test points, test sequence and experimental plan [5] for the deduced sets of independent pi term.
It is necessary to decide the range of variation of the variable governed by the constraints of cost, time of fabrication and experimentation and computation accuracy the test envelopes are decided. On the basis of ranges of variation of the independent variable, the ranges of variation of independent dimensionless groups have been calculated and are shown in Table 2.
During experimentation, at a time, the value of one of the independent dimensionless group will be varied, keeping the values of rest of the independent dimensionless groups constant. Thus classical plan of experimentation is adopted. Test sequence is random as experimentation is reversible. This random order for the independent dimensionless group is indicated by Roman letters in Table 2.

2.D DESIGN OF THE EXPERIMENTAL SETUP

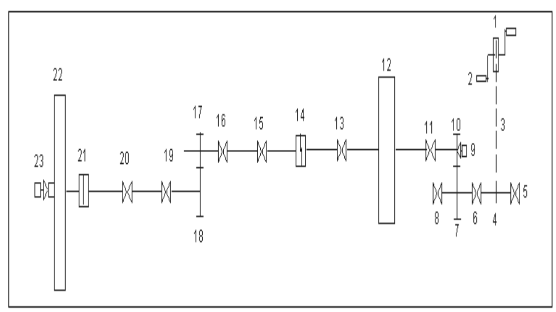

Fig.2: Assembly drawing of Human Powered Fodder -Chopper Machine

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 shaft21-Coupling 22-Chaff Cutter blade 23-Tachogenerator for chaff Cutter shaft.
Figure 2, Describe the experimental setup having the provision of varying all independent pi terms

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31st May 2010. Vol.15. No.2.

www.jatit.org

of Equation 1, 2 and 3. This experimentation necessitates development of precise angular speed measuring system .The development of electronic circuitry based measuring system for this purpose is detailed as below.

The costly techniques of high resolution shaft encoders would have required the other complicated interface circuits. Hence an attempt is made to measure and plot the two speeds (flywheel shaft and load shaft) in time domain by much simpler gadget Tachogenerator.

The analog signal from the shaft Tachogenerator were fed to the digital oscilloscope, thereby converting the same to d .c voltage. This d .c voltage is then fed to a computer provided with software SP 107 (digital oscilloscope software). The on line data was then picked up and stored in the computer's memory. The graphical manipulation of this data with the help of Excel was done to obtain the desired resolution of graphs.

Two sets of spur gears are fabricated as per experimental plan. These gears can be change by dismantling them from their shafts and replacing them by a new pair. Tachogenerator are connected to flywheel shaft and cutter shaft. Two sets of chaff cutter (22) as per the experimental plan were changed by dismantling them from their shafts.

The flywheel was equipped with a D.C Tachogenerator mounted on the flywheel shaft (9) linked to computer. For deciding the instant when to engage the clutch a hand Tachometer was used to decide flywheel speed at which the clutch is planned to be engaged. Another Tachogenerator is mounted on shaft of the chaff cutter shaft (23), to measure the speed of cutter shaft. The three digit object counter is also attached to read the number of cuts .Number of cuts was also evaluated on the basis of speed plots obtained during experimentation.

Both the Tachogenerator are connected to computer which form a computerized instrumentation system. The developed measuring system gives quite a satisfactory performance.

2.E COLLECTION AND PURIFICATION OF THE EXPERIMENTAL DATA

The experimentation is performed as per the experimental plan and the values of the independent and dependent pi terms for each test run . Proper precautions were taken during the test run and for any erroneous data for a test run the test are repeated.

2.F DEVELOPMENT OF EXPERIMENTAL DATA BASED MODEL

A quantitative relationship is to be established amongst the responses and the inputs. The inputs are varied experimentally and the corresponding responses are measured. Such relationships are known as models. The observed data of dependent parameters for the redesigned independent parameters of the system has been tabulated. In this case there are dependent and independent pi terms. It is necessary to correlate quantitatively various independent and dependent pi terms involved in this man-machine system.

This correlation is nothing but a mathematical model as a design tool for experimental setup of such workstations. The optimum values of the independent pi terms can be decided by optimization of these models for maximum productivity, and minimum torque, cutting time.

An approximate generalized experimental data based models for the human-powered chaff cutting machine system has been established for responses of the system such as Instantaneous Resistive Torque (π_{D1}), Number of Cuts (π_{D2}) and Process Time (π_{D3}).

The models are:

$$\pi_{D1}=1.645\times10^{13}(\pi_1)^{3.8074}(\pi_2)^{0.5141}(\pi_3)^{-0.4521}(\pi_4)^{1.6861}(\pi_5)^{2.3237}(\pi_6)^{0.8162}(\pi_7)^{-0.4189}(\pi_8)^{-0.3840}$$

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

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

respectively.

Thus corresponding to the three dependent pi terms we have formulated three models from the set of observed data for Experimental seat. From these models values of all the dependent pi terms are computed and entered in Table 3. The respective regression coefficients between observed and computed values of the all the three dependent pi terms are calculated and shown in the table 3.

3. COMPUTATION OF THE PREDICTED VALUES BY 'ANN'

One of the main issues in research is prediction of future results. The experimental data based

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31st May 2010. Vol.15. No.2.

www.jatit.org

modeling achieved this through mathematical models for the three dependent pi terms Instantaneous Resistive Torque (π_{D1}), Number of Cuts (π_{D2}) and Process Time (π_{D3}). In such complex phenomenon involving non-linear systems it is also planned to develop artificial neural network (ANN). The output of this network can be evaluated by comparing it with observed data and the data calculated from the mathematical models. For development of ANN the designer has to recognize the inherent patterns. Once this is accomplished training the network is mostly a fine-tuning process. An ANN consists of three layers of nodes viz. the input layer, the hidden layer or layers (representing the synapses) and the output layer. It uses nodes to represent the brains neurons and these layers are connected to each other inlayers of processing. The specific mapping performed by ANN depends on its architecture and values of synaptic weights between the neurons. ANN as such is highly distributed representation and transformation that operate in parallel and has distributed control through many highly interconnected nodes. ANN were developed utilizing this black box concepts. Just as human brain learns with repetition of similar stimuli, an ANN trains itself within historical pair of input and output data usually operating without a priory theory that guides or restricts a relationship between the inputs and outputs. The ultimate accuracy of the predicted output, rather than the description of the specific path(s) or relationship(s) between the input and output, is the goal of the model. The input data is passed through the nodes of the hidden layer(s) to the output layer, a non linear transfer function assigns weights to the information as it passes through the hidden layer nodes; mimicking the transformation of information as it passes through the brains synapses. The role of ANN model is to develop a response by assigning the weights in such a way that it represents the true relationship that really exists between the inputs as and output. During training, the ANN effectively interpolates a function between the input and output neurons. ANN does not build an explicit description of this function. The prototypical use of ANN is in structural pattern recognition. In such a task, a collection of features is presented to the ANN and it must be able to categories the input feature pattern as belonging to one or more classes. In such cases the network is presented with all relevant information simultaneously.

4. A PROCEDURE FOR MODEL FORMULATION IN ANN

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 under

i) 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.

ii) The input and output data is then read by the using the DLMREAD function.

iii) In preprocessing step the input and output data is normalized.

iv) Through principle component analysis the normalized data is uncorrelated. This is achieved by using prepca 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 g, last 75% data for validation and middle overlapping 50% data for training. This is achieved by developing a proper code.

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

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

vii) 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 shown in the Fig 3,4,5. The error in the target (T) and the actual data (A) are represented in graphical form.

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

ix) The regression analysis and the representation are done through the standard functions.

The values of regression coefficient and the equation of regression lines are represented on the three different graphs plotted, Figure 5, 6, 7

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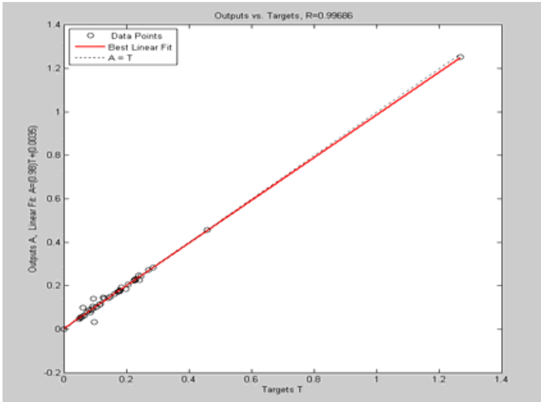

Fig.3. Comparison of Experimental and Computed data by A.N.N (π_{D1})

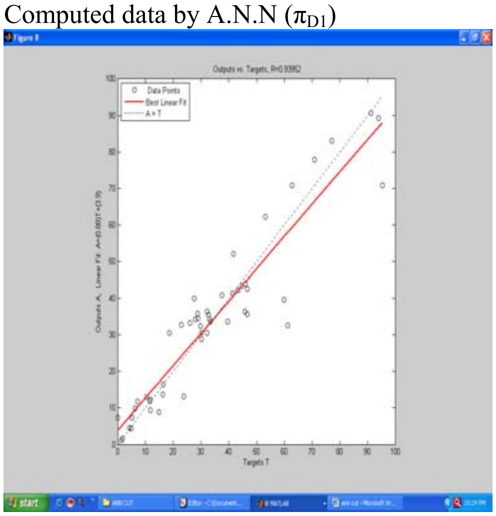

Fig.4. Comparison of Experimental and Computed data by A.N.N (for π_{D2})

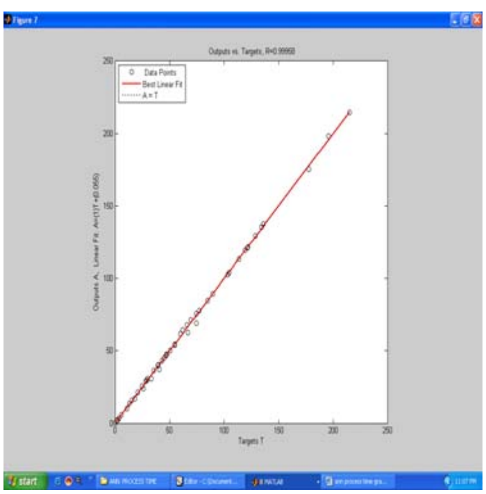

Fig.5. Comparison of Experimental and Computed data by A.N.N (π_{D3})

The values of regression coefficient and the equation of regression lines are represented on the three different graphs plotted for the three dependent pi terms viz. Instantaneous Resistive Torque (π_{D1}), Number of Cuts (π_{D2}) and Process Time (π_{D3}).

The output of this network can be evaluated by comparing it with observed data and the data calculated from the mathematical models & A.N.N model Table:3. The values of regression coefficient and the equation of regression lines are represented on the three different graphs plotted, Figure: 6 (a,b,c) for the three dependent pi terms viz Resistive torque, Number of Cuts, Process time . Fig.3(a,b,c) Comparison between Experimental Data ,Mathematical Modeling Equation and Neural data of (π_{D1}), (π_{D2}), (π_{D3}).

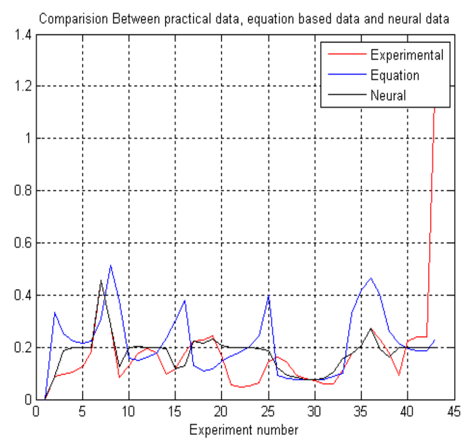

Fig.6(a). Comparison of Experimental Computed and data by A.N.N (π_{D1})

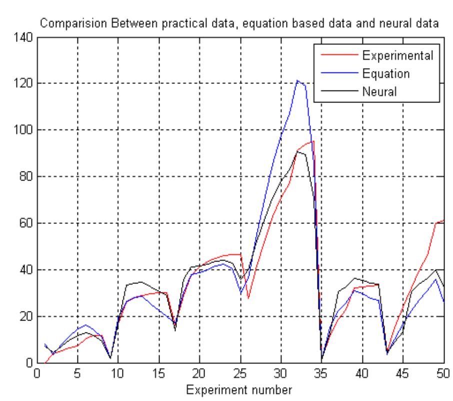

Fig.6(b). Comparison of Experimental and Computed data by A.N.N (π_{D2})

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31st May 2010. Vol.15. No.2.

www.jatit.org

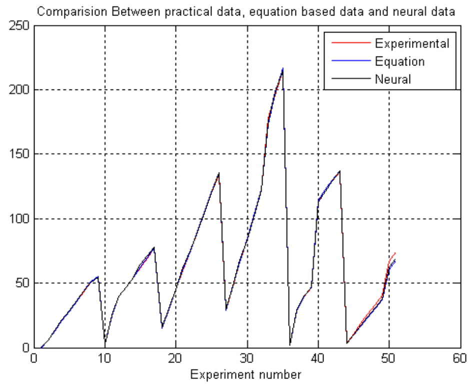

Fig . 6(c) Comparison of Experimental Computed and data by A.N.N (π_{D3})

5. CONCLUSION

The empirical models predict the performance of the Human Powered Fodder Chopper. The Optimum values of various independent parameters were arrived at on the basis of optimization of the models. The optimum values of independent Pi terms are
$\pi_1 = 5.33x10^{-5}$, $\pi_2 = 1.47x10^{-5}$, $\pi_3 = 3.77$, $\pi_4 = 3$, $\pi_5 = 0.122$, $\pi_6 = 2$, $\pi_7 = 214.86$, $\pi_8 = 141.2$ for minimization of resistive torque,
$\pi_1 = 5.33x10^{-5}$, $\pi_2 = 1.47x10^{-5}$, $\pi_3 = 3.769$, $\pi_4 = 3$, $\pi_5 = 0.122$, $\pi_6 = 3$, $\pi_7 = 215.23$, $\pi_8 = 141.65$ for maximization of number of Cuts and
$\pi_1 = 5.33x10^{-5}$, $\pi_2 = 1.47x10^{-5}$, $\pi_3 = 1$, $\pi_4 = 3$,
$\pi_5 = 0.122$, $\pi_6 = 3$, $\pi_7 = 1.86$, $\pi_8 = 35.41$ for minimization of Process time.

A new theory of cutting of chaff from the Human Powered chaff cutting machine is proposed. This hypothesis states that on engagement of the clutch, the speed of flywheel initially rises suddenly to maximum value indicating energy loss of stored energy in flywheel. A major part of this energy loss is due to 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 chaff cutter shaft. The proposed flywheel motor can be used as energy source for any process unit that can operate with its input shaft in a transient state of motion and not much effecting quality of product.

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 human powered flywheel motor can be used as an energy source for processes which need even up to 6 h.P and if the end product quality does not get much affected by the dropping speed.

The mathematical models and an ANN Simulation developed for the phenomenon truly represent the degree of interaction of various independent variables.

which,($\pi_1 = \frac{dW_b t_b}{D^3}$) is the most sensitive and ($\pi_2 = \frac{D^4 E}{gI}$)is the least sensitive for ($\pi_{D1} = \frac{D}{gI} T_c$)and($\pi_{D2} = C$)respectively. Whereas in $\pi_{D3} = \sqrt{\frac{g}{D}} t_p$, π_2 is the most sensitive and π_1 is the is the least sensitive.

This is made possible only by approach adopted in this investigation.

Through sensitivity analysis the conclusions are the trends for the behaviors of the models in least sensitive. The Standard error of estimate of the predicted or computed values of the dependent variables is found to be very low viz $\pi_{D1}=0.026$, $\pi_{D2}=3.39$, $\pi_{D3}=0.639$. This gives authenticity to the developed mathematical models and an ANN.

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

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 many rural based process machines in places where reliability of availability of electric energy is much low.

6. LIMITATIONS OF THE PRESENT WORK

The ANN performance depends on the training.
The comparative lower value of the regression Coefficient for one of the dependent Pi terms may be due to the improper training of the network.
The ANN is unable to predict beyond the range of independent Pi terms for which it is trained.

a) The adopted models of this study are formulated for the chaff cutting. These models can not be applied to cut the stacks of other food grains.

b) The mathematical models are formulated for the particular test envelope. Beyond this

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www.jatit.org

envelope the models will not predict the performance of the system.
c) The instantaneous load torque is deduced applying the concept of basic mechanics .It is not experimentally measured. This may introduce error to the extend of 1% because of estimation of slope at various points of chaff cutter speed versus time plot.

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