FORMULATION OF DATA BASED ANN MODEL FOR HUMAN POWERED OIL PRESS

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ABSTRACT

The paper presents to formulate an experimental data based ANN model for a Human Powered oil Press. 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 Oil Press 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 parameters for the designed Oil Press to match the features of the machine operator performing the Oil Press task so as to maximize the Quantity of Oil Extracted and minimize Instantaneous torque, and instantaneous angular velocity of shaft of presser. 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, Oil Press, 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.

2. MATERIALS AND METHODS

2.1 Experimental Approach

In the oil Pressing 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.

1. Identification of independent, dependent and extraneous Variables.
2. Reduction of independent variables adopting dimensional analysis
3. Test planning comprising of determination of Test Envelope, Test Points, Test Sequence and Experimentation Plan.
4. Physical design of an experimental set-up.
5. Execution of experimentation
6. Purification of experimentation data
7. Formulation of model.
8. Reliability of the model.
10. ANN Simulation of the experimental data.

The first six steps mentioned above constitute design of experimentation. The seventh step constitutes model formulation where as eighth and ninth steps are respectively reliability of model and optimization. The last step is ANN Simulation of model.

2.2 Identification of Independent and Dependent Variables

The Independent and Dependent variables for human powered oil seed press was identified and are as tabulated in Table No.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 No. 1 Description of Dependent and Independent Variables

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Description of Variables</th>
<th>Types of Variables</th>
<th>Symbols</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Base dia. Of screw shaft</td>
<td>Independent</td>
<td>$d_b$</td>
<td>L</td>
</tr>
<tr>
<td>2</td>
<td>Max. dia. Of screw shaft</td>
<td>Independent</td>
<td>$d_m$</td>
<td>L</td>
</tr>
<tr>
<td>3</td>
<td>Length of Taper</td>
<td>Independent</td>
<td>$L_t$</td>
<td>L</td>
</tr>
<tr>
<td>4</td>
<td>Diameter of Barrel</td>
<td>Independent</td>
<td>D</td>
<td>L</td>
</tr>
<tr>
<td>5</td>
<td>Speed of Rotation at engagement</td>
<td>Independent</td>
<td>$\omega_e$</td>
<td>T&lt;sup&gt;-1&lt;/sup&gt;</td>
</tr>
<tr>
<td>6</td>
<td>Pitch of Helix</td>
<td>Independent</td>
<td>P</td>
<td>L</td>
</tr>
<tr>
<td>7</td>
<td>Input energy to Machine</td>
<td>Independent</td>
<td>E</td>
<td>ML&lt;sup&gt;-2&lt;/sup&gt;T&lt;sup&gt;-2&lt;/sup&gt;</td>
</tr>
<tr>
<td>8</td>
<td>Acceleration Due to gravity</td>
<td>Independent</td>
<td>g</td>
<td>LT&lt;sup&gt;-2&lt;/sup&gt;</td>
</tr>
<tr>
<td>9</td>
<td>Gear ratio of torque amplification</td>
<td>Independent</td>
<td>G</td>
<td>M&lt;sup&gt;1&lt;/sup&gt;L&lt;sup&gt;m&lt;/sup&gt;T&lt;sup&gt;-m&lt;/sup&gt;</td>
</tr>
<tr>
<td>10</td>
<td>Crushing strength of material process</td>
<td>Independent</td>
<td>$T_c$</td>
<td>ML&lt;sup&gt;-1&lt;/sup&gt;T&lt;sup&gt;-2&lt;/sup&gt;</td>
</tr>
<tr>
<td>11</td>
<td>Avg. size of oil seed</td>
<td>Independent</td>
<td>S</td>
<td>L</td>
</tr>
<tr>
<td>12</td>
<td>Quantity of raw material admitted per cycle pressing</td>
<td>Independent</td>
<td>$Q_R$</td>
<td>M</td>
</tr>
<tr>
<td>13</td>
<td>Instantaneous time</td>
<td>Independent</td>
<td>t</td>
<td>T</td>
</tr>
<tr>
<td>14</td>
<td>Crushing strength of material of screw</td>
<td>Independent</td>
<td>$T_s$</td>
<td>ML&lt;sup&gt;-1&lt;/sup&gt;T&lt;sup&gt;-2&lt;/sup&gt;</td>
</tr>
<tr>
<td>15</td>
<td>Load Torque</td>
<td>Dependent</td>
<td>$T_{shaft}$</td>
<td>ML&lt;sup&gt;-1&lt;/sup&gt;T&lt;sup&gt;-2&lt;/sup&gt;</td>
</tr>
<tr>
<td>16</td>
<td>Quantity of oil extracted</td>
<td>Dependent</td>
<td>$Q_o$</td>
<td>M</td>
</tr>
<tr>
<td>17</td>
<td>Instantaneous angular velocity of the shaft of presser</td>
<td>Dependent</td>
<td>$\omega_r$</td>
<td>T&lt;sup&gt;-1&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

2.3 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 into few dimensionless pi terms. The independent and the dependent pi terms as formulated are shown in the Table No.1. Thus there are fourteen independent pi terms and three dependent pi terms in this experimentation. Applying Buckingham $\pi$ theorem, the dimensional equations for Instantaneous Load Torque, Quantity of Oil Extracted, and Instantaneous angular velocity of the shaft of the presser are formulated as under.
Instantaneous Load Torque

\[
\frac{\omega^6}{E g^4} T_{\text{shaft}} = f_1 \left[ \left( \frac{\omega^2}{g} d_b \right) \left( \frac{\omega^2}{g} d_m \right) \left( \frac{\omega^2}{g} L_t \right) \left( \frac{\omega^2}{g} D \right) \left( \frac{\omega^2}{g} P \right) \left( \frac{r_2}{r_3} \right) \left( \frac{\omega^2}{g} S \right) \left( \frac{\omega^6}{E g^4 Q_R} \right) (\omega t)G \right] \tag{1}
\]

Quantity of Oil Extracted

\[
\frac{q_0 \omega^6}{E g^2} = f_2 \left[ \left( \frac{\omega^2}{g} d_b \right) \left( \frac{\omega^2}{g} d_m \right) \left( \frac{\omega^2}{g} L_t \right) \left( \frac{\omega^2}{g} D \right) \left( \frac{\omega^2}{g} P \right) \left( \frac{r_2}{r_3} \right) \left( \frac{\omega^2}{g} S \right) \left( \frac{g^2}{E \omega^2 Q_R} \right) (\omega t)G \right] \tag{2}
\]

Instantaneous angular velocity of the shaft of the presser

\[
\frac{\omega_r}{\omega} = f_3 \left[ \left( \frac{\omega^2}{g} d_b \right) \left( \frac{\omega^2}{g} d_m \right) \left( \frac{\omega^2}{g} L_t \right) \left( \frac{\omega^2}{g} D \right) \left( \frac{\omega^2}{g} P \right) \left( \frac{r_2}{r_3} \right) \left( \frac{\omega^2}{g} S \right) \left( \frac{g^2}{E \omega^2 Q_R} \right) (\omega t)G \right] \tag{3}
\]

In Eq. 1,2 and 3 ‘f’ stands for ‘function of’.

2.4 Test Planning

This comprises of deciding test envelope, test points, test sequence and experimental plan [ ] 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. 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.

2.5 Design of Experimental Setup

It is necessary to evolve physical design of an experimental set up having provision of setting test points, adjusting test sequence, executing proposed experimental plan, provision for necessary instrumentation for noting down the responses and independent variables. From these provisions one can deduce the dependent and independent pi-terms of the dimensional equation. The experimental set up is designed considering various physical aspects of its elements. For example, if it involves a gear, then it has to be designed applying the procedure of the gear design. In this experimentation there is a scope for design as far as oil seed presser is concerned from the strength considerations. The other dimensions of the oil seed presser are designed using previous mechanical design experience and practice under the presumption of process operation at constant feed condition. This is so because only that data is available.

Experimental set up is designed for the above stated criteria, so that the pre decided test points can be set properly within the test envelope proposed in the experimental plan. The procedure of design of experimental set up, however cannot be totally followed in the field experimentation. This is so because in the field experimentation, we are carrying out the experimentation using the available ranges of the various independent variables to assess the value of the dependent variable.
Fig. 1 Assembly drawing of Human Powered oil press

1-Handle               13- Bearing
2-Seat for Driver         14- Flywheel
3-Paddles                   15- Spiral Clutch
4-Sprocket wheel           16- Bearing
5- Roller chain      17- Bearing
6- Free wheel with smaller sprocket       18- Pinion
7- Flywheel shaft         19- Gear
8-Bearing         20- Bearing
9- Bearing          21- Bearing
10-Gear                                              22- Barrel of oil seed presser
11- Pinion                  23- Wire wound Presser shaft
12- Bearing      24- Hopper

2.6 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.

2.7 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 Quantity of oil extracted and angular velocity of the shaft of presser and minimum Load Torque.

An approximate generalized experimental data based models for the human-powered oil press system has been established for responses of the system such as Instantaneous Load Torque ($\pi_{01}$), Quantity of oil Extracted ($\pi_{02}$), Instantaneous angular velocity of the shaft of presser ($\pi_{03}$)
The models are:

\[
\pi_{01} = 1(\pi_1)^{0.8186} (\pi_2)^{2.6086} (\pi_3)^{-5.1109} (\pi_4)^{1.9233} (\pi_5)^{0.1025} (\pi_6)^{1.7301} \tag{4}
\]

\[
\pi_{02} = 1(\pi_1)^{0.1063} (\pi_2)^{0.3919} (\pi_3)^{-0.4819} (\pi_4)^{-0.7519} (\pi_5)^{-0.0135} (\pi_6)^{0.1903} \tag{5}
\]

\[
\pi_{03} = 1(\pi_1)^{-0.1874} (\pi_2)^{-0.9761} (\pi_3)^{-1.4477} (\pi_4)^{-0.0745} (\pi_5)^{-0.5860} (\pi_6)^{-0.5550} \tag{6}
\]

Thus corresponding to the three dependent \( \pi \) terms we have formulated three models from the set of observed data.

2.8 Computations of the Predicted Values by ‘ANN’

One of the main issues in the research is prediction of future results. The experimental data based modeling achieved through mathematical models for the dependent \( \pi \) terms. In such complex phenomenon involving non linear systems, it is also planned to develop a models using 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 neurons of brain and these layers are connected to each other in layer of processing. The specific mapping performed by ANN depends on its architecture and values of synaptic weights between neurons. ANN were developed utilizing this black box concepts. Just as human brain learns with repetition of similar stimuli, an ANN trains itself within the historical pair of input and output data, usually operating without proxy theory that guides or restricts a relationship between the inputs and outputs. The ultimate accuracy of 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 the weights to the information, as it passes the hidden layer nodes, mimicking the transformation of information, as it passes through the brains synapses. The role of the ANN model is to develop the response by assigning the weights in such a way that it represents the true relationship that really exists, between the input and output. During training, the ANN effectively interpolates the function between the input and output neurons. ANNs do not build an explicit description of this function. The prototypical use of ANN is in structural pattern recognition. In such 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.

2.9 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 the ANN model for these complex phenomenon. The various steps followed in the developing algorithm to form ANN are as given below.

i. The observed data from the experimentation is separated into two parts viz. input data or the data of independent \( \pi \) terms and 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 using the DLMREAD function.

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

iv. Through the principle component analysis the normalized data is uncorrelated. This is achieved by using PREPCA function. The input and output data is then 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.

v. The data is then stored in structures of testing, validation and training.

vi. By observing 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 and graphs have been plotted. 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. Programming of ANN is given in Appendix C.

Fig. 2 Network of ANN

Fig. 3 Comparison of Experimental and Empirical prediction and ANN prediction for output $\pi_{01}$
3. CONCLUSION

The empirical models predict the performance of the Human Powered oil press. 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

\[\pi_1 = 82869.5, \pi_2 = 0.01999999836, \pi_3 = 3.624, \pi_4 = 3700.8, \pi_5 = 5.8629 \text{ and } \pi_6 = 1.999953.\]

For minimization of instantaneous load Torque,
\[\pi_1 = 6769175.3, \pi_2 = 0.01999999836, \pi_3 = 3.624, \pi_4 = 18747, \pi_5 = 2450 \text{ and } \pi_6 = 5.999991.\]

For maximization of Quantity of oil extracted and
\[\pi_1 = 82869.5, \pi_2 = 0.01999999836, \pi_3 = 3.624, \pi_4 = 3700.8, \pi_5 = 2450 \text{ and } \pi_6 = 1.999953.\]

For maximization of instantaneous angular velocity of the shaft of presser.

A new theory of pressing of oil seed from the Human Powered oil press 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 shaft due to persistent presence of pressing action.
It is further hypothesized that the quantity of oil extracted is a function of available energy for pressing, resisting torque and average angular speed of the oil press 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 affecting 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 hp 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.

\[
\pi_3 = \frac{\omega^2}{g} S
\]

is the most sensitive \( (\pi_5 = \omega t) \) is the least sensitive for \( (\pi_{01} = \frac{\omega^8}{Eg^2 T_{shaft}}) \)

\[
\pi_{4} = \frac{\omega^6}{Eg^2 Q_R}
\]

is the most sensitive and \( (\pi_5 = \omega t) \) is the least sensitive for \( (\pi_{02} = \frac{Q_o \omega^6}{E g^2}) \)

\[
\pi_6 = [G]
\]

is the most sensitive and \( (\pi_4 = \frac{\omega^6}{Eg^2 Q_R}) \) is the least sensitive. for \( (\pi_{03} = \frac{\omega r}{\omega}) \)

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 \( \pi_{01} = 0.0807, \pi_{02} = 0.0698, \pi_{03} = 0.0586 \). 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.

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.

4. 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 peanuts. These models cannot be applied to other oil seeds.

b) The mathematical models are formulated for the particular test envelope. Beyond this 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 extent of 1% because of estimation of slope at various points of oil press speed versus time plot.
REFERENCES