RESEARCH ARTICLE OPEN ACCESS

Design of Experimentation, Artificial Neural Network Simulation and Optimization for Integrated Bamboo Processing Machine

P. G. Mehar[1], Dr. A. V. Vanalkar[2], Dr. S. S. Khandare[3]
[1]Research Scholar
[2]Professor, Deptt. of Mech. Engg. K. D. K. College of Engg. Nagpur (M.S.), India
[3]Ex-Principal, B. D. College of Engg. Sevagram, Wardha (M.S.), India

Abstract
In this research work experimentation on integrated bamboo processing machine for splitting and slicing of bamboo has been carried out. This paper presents the experimental investigation of some parameters of integrated bamboo processing machine. In this research paper simulation of experimental data using artificial neural network is carried out. An attempt of minimum-maximum principle has been made to optimize by range bound process for maximizing production rate of integrated bamboo processing machine.
Key Words: - Bamboo, Splitting, slicing, experimentation, ANN, optimization.

I. INTRODUCTION

The initial process includes Splitting, External and Internal Knot Removing, Slicing, Bamboo sticking making, Stick length setting, Stick Polishing [13]. The initial processes carried out on a bamboo to make it as a useful product is called as bamboo processing. Bamboo and bamboo splits are used as the fencing material and for making various types of tool handles, ladders and scaffolding. Splits as well as slivers are used to make a wide range of products such as baskets, the core of incense-sticks, kites and toys, flutes and a large number of handicraft items [1]. Traditionally the bamboo is processed in different steps and for each step a different machine is required. The main aim is to develop an integrated bamboo processing machine to reduce the number of steps and also to reduce the number of machines required to complete the desired work. So an integrated bamboo processing machine is fabricated which can perform splitting and slicing on a single machine.

II. EXPERIMENTAL SETUP

Traditionally bamboo slicing is done manually, or by using a manually operated machine, there was always a need of machine which will gives slices of bamboo without splitting operation. Integrated bamboo processing machine reduces the cost as well as time for processing bamboo in to slices. In this research work dependent and independent variables are identified then experimental data is collected [3]. The experimental set up is as shown in figure 1. It shows the Integrated Bamboo processing Machine, load cell, stop watch and energy meter.

Fig. 1: Experimental Set-up along with measuring devices
a) Load cell b) Stop watch c) Energy meter

III. Experimental Investigation

The data of Bamboo processing is not known to the professionals involved in this type of operations. The quantitative relationship based on logic is not possible and hence the only alternative is of formulating experimental data based model.

The approach adopted for formulating generalized experimental data based model is suggested by Hilbert Schenck [8] as given below.

1. Identification of independent and dependent variables or quantities.
2. Reduction of independent variables adopting dimensional analysis.
3. Design of experimental set up.
4. Calibration of an instrument.
5. Measurement of experimental data.
6. Model Formulation
7. Optimization and validation
8. ANN simulation

The formulated model is an approximate generalized model. The Identification of dependent and independent variables of the phenomenon is to be carried out based on known qualitative physical phenomenon.

IV. IDENTIFICATION OF VARIABLES

The parameters [9] which affect the production rate, quality and efficiency of machine are selected are tabulated in the below table 1.

Sr. No.	Variable	Types of Variable	Symbol	Dimensions
1.	Tool Hardness	Independent	H_T	-
2.	Relief Angle	Independent	Ø	-
3.	Condition of Bamboo	Independent	B_T	-
4.	Rake Angle	Independent	α	-
5.	Outer Diameter of bamboo	Independent	Do	L
6.	Inner Diameter of bamboo	Independent	Di	L
7.	Force	Independent	F	MLT^{-2}
8.	Velocity	Independent	Vp	LT^{-1}
9.	Input Energy	Independent	I_E	ML^2T^{-2}
10.	Work Done	Independent	W_d	ML^2T^{-2}
11.	Production Rate	Dependent	P_R	T^{-1}
12.	Quality	Dependent	Q	-
13.	Efficiency	Dependent	η	-

Table 1: Parameters affecting bamboo processing

V. TABULATION OF DATA

The collected data from the experimentation is tabulated in a proper format as given below in table 2.

Input Variable											Output Variable		
Sr. No.	Tool Hardness, H_T (BHN)	Relief Angle, ø	Condition of Bamboo, B_T	Rake Angle, α	Outer diameter of Bamboo, do (mm)	Inner diameter of Bamboo, di (mm)	Force, F (N)	Velocity, Vp (m/sec)	Input Energy (KJ)	Work Done (KJ)	Production Rate of (No. Slice/sec.)	Quality (degree)	Efficiency, (%)
	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	Y_1	Y_2	Y_3
1	260	25	2	0	50	30	122.63	0.53	0.197	0.176	2.21	160	89.35
2	260	25	2	0	53	21	147.15	0.54	0.259	0.226	1.49	165	87.05
3	260	25	2	0	52	25	141.26	0.56	0.238	0.212	1.56	155	89.18
4	260	25	2	0	45	27	117.72	0.54	0.174	0.149	1.55	155	85.91
5	260	25	2	0	45	0	153.04	0.56	0.224	0.194	0.97	170	86.42
6	260	25	2	0	43	0	152.06	0.51	0.207	0.182	0.88	180	87.99
7	260	25	2	0	51	0	159.90	0.56	0.266	0.235	0.96	180	88.12
8	260	25	2	0	53	0	163.83	0.54	0.282	0.251	0.94	180	89.02
9	260	25	1	0	51	30	126.55	0.56	0.212	0.186	1.70	140	87.44
10	260	25	1	0	53	21	147.15	0.56	0.259	0.226	1.49	145	87.05

Table 2: Experimental data sample readings

VI. ARTIFICIAL NEURAL NETWORK (ANN)

The ANN simulation [6][12] is carried out for the experimental data to validate the model for large number of readings. The simulation also improves the model which is obtained by multivariable linear regression model. The simulated model ensures more accurate prediction of values.

6.1 SIMULATION BY USING MATLAB

The ANN simulation is carried out by using MATLAB software. The simulation for 1296 readings is carried out on artificial neurons.

6.2 PRODUCTION RATE (Y_1)

ANN is used for validating the input data and output data (Y_1).

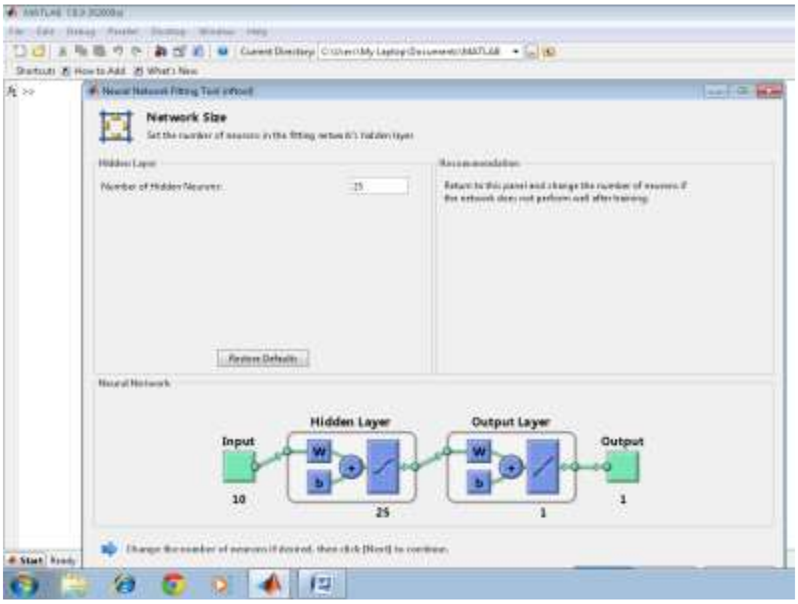

Fig. 2: Network size

Figure 2 shows that ready to create a network and train it. It is tried for a two layer network, with sig-mod transfer function in hidden layer and a linear function in an output layer. As an initial guess, here 25 hidden neurons in hidden layers are used. The network has 10 inputs and 1 output.
Here Leven berg – Marquartt algorithm for training is used. The network is trained for 20 iterations only and three targets, training, validations and testing of data samples.

Fig. 3: Network train for data validation

Network train for data validations is shown in figure 3 results in progress of 20 epochs, time required training the network and various performances of parameters. It clearly shows the size validation checks.

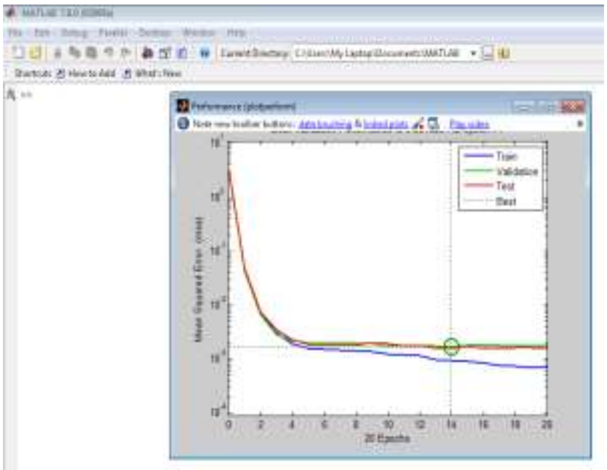

Fig. 4: Performance of the learning algorithm train over 20 epoch

The training stops after 20 iterations because validations error increased as shown in figure 4. It is useful diagnostic tool to plot the training, validations and test error to check the progress of training. The results are shown in figure 4. The test error and validation set error have similar characteristics and does not appear that any significant over fitting has occurred. The goal is to design the production rate and having minimum errors. The best validation performance is 10^{-3} at 14 epochs.

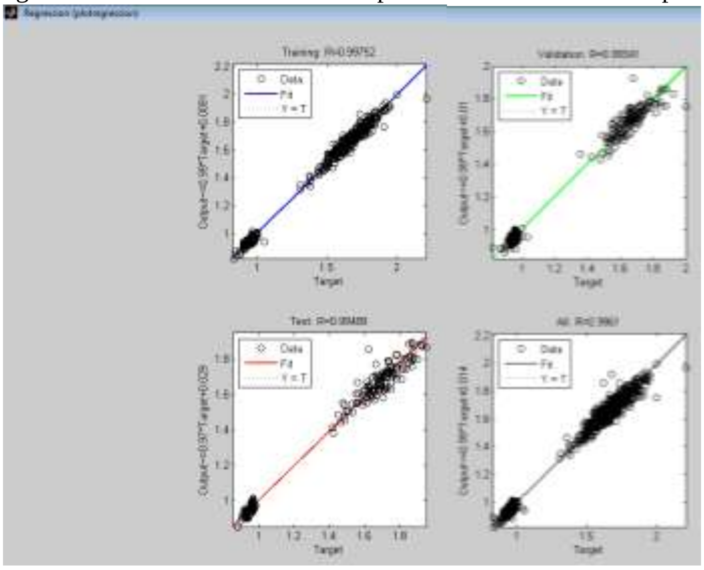

Fig. 5: Linear regression performance fitness curve

The next step is to perform some analysis of the network response. Put the entire data set through the network (training, validation and test) as shown in figure 5, and perform a linear regression between network outputs and the corresponding targets. First calculate the network outputs, in this case there are single outputs and three targets. As shown the result of first three figures, the regression values around 0.9 to achieve the targets.

6.3 QUALITY (Y_2)

ANN is used for validating the input data and output data (Y_2).

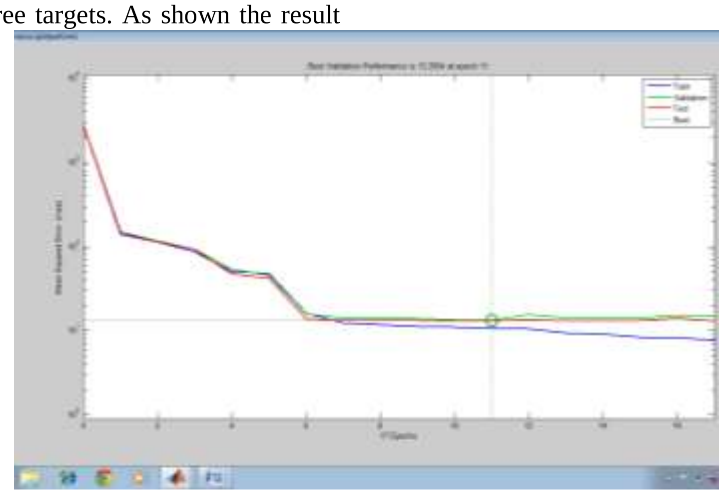

Fig. 6: Performance of the learning algorithm train over 17 epoch

The training stops after 17 iterations because validations error increased as shown in figure 6. It is useful diagnostic tool to plot the training, validations and test error to check the progress of training. The results are shown in figure 6. The test error and validation set error have similar characteristics and does not appear that any significant over fitting has occurred. The goal is to design the quality and having minimum errors. The best validation performance is 10^1 at 11 epochs.

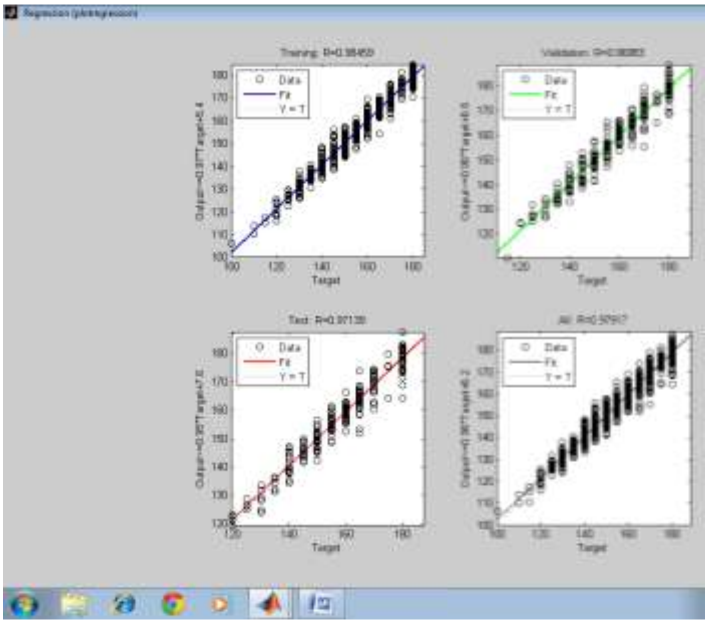

Fig. 7: Linear regression performance fitness curve

The next step is to perform some analysis of the network response. Put the entire data set through the network (training, validation and test) as shown in figure 7, and perform a linear regression between network outputs and the corresponding targets. First calculate the network outputs, in this case there are single outputs and three targets. As shown the result of first three figures, the regression values around 0.9 to achieve the targets.

6.4 EFFICIENCY (Y_4)

ANN is used for validating the input data and output data (Y_4).

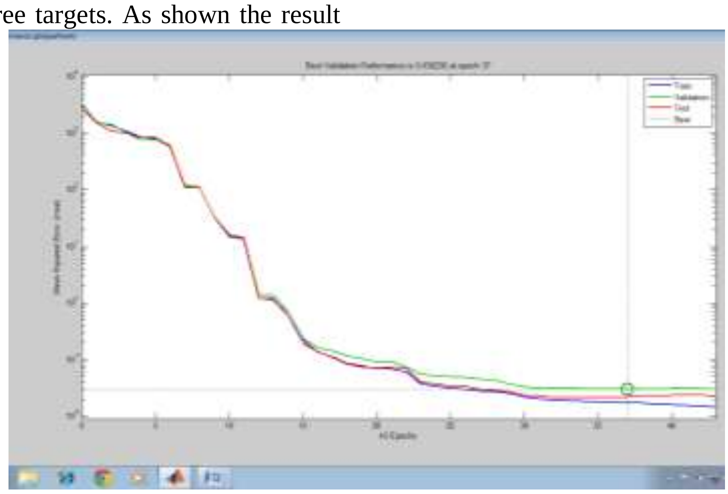

Fig. 8: Performance of the learning algorithm train over 43 epoch

The training stops after 43 iterations because validations error increased as shown in figure 8. It is useful diagnostic tool to plot the training, validations and test error to check the progress of training. The results are shown in figure 8. The test error and validation set error have similar characteristics and does not appear that any significant over fitting has occurred. The goal is to design the efficiency and having minimum errors. The best validation performance is $10^{-1.5}$ at 37 epochs.

The next step is to perform some analysis of the network response. Put the entire data set through the network (training, validation and test) as shown in figure 9, and perform a linear regression between network outputs and the corresponding targets. First calculate the network outputs, in this case there are single outputs and three targets. As shown the result of first three figures, the regression values around 0.9 to achieve the targets.

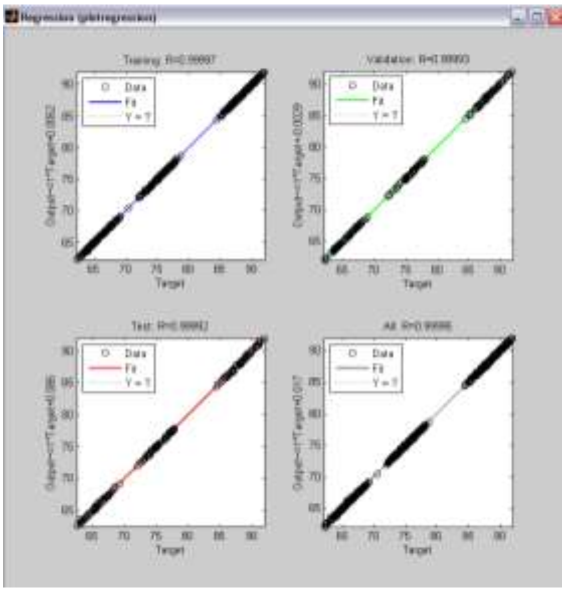

Fig. 9: Linear regression performance fitness curve

VII. OPTIMIZATION

The manual optimization is performed by using the Range Bound Optimization method [4] of operations research. The optimization is done for maximum production rate and minimum power consumption.

7.1 MAXIMIZATION OF PRODUCTION RATE

In order to obtain maximum production rate the objective function of production rate is used.

Max $Y_1 = 1.154651 - 6.2E\text{-}05X_1 + 0.000347X_2 - 0.00445X_3 - 0.00196X_4 - 0.02525X_5 + 0.028952X_6 - 0.00284X_7 + 1.165921X_8 + 0.27392X_9 + 3.523711X_{10}$

Subjected to constraints of different variables present in table 2,

$210 \leq X_1 \leq 269$; $15 \leq X_2 \leq 25$; $1 \leq X_3 \leq 2$; $0 \leq X_4 \leq 4$; $40 \leq X_5 \leq 56$; $0 \leq X_6 \leq 36$;
$98.10 \leq X_7 \leq 168.73$; $0.48 \leq X_8 \leq 0.58$; $0.127 \leq X_9 \leq 0.408$; $0.114 \leq X_{10} \leq 0.276$

For obtaining maximum production rate, the input variables with negative sign in model are chosen with lowest value and positive sign in model are chosen with highest value.

$X_1 = 210$; $X_2 = 25$; $X_3 = 1$; $X_4 = 0$; $X_5 = 40$; $X_6 = 36$;
$X_7 = 98.10$; $X_8 = 0.58$; $X_9 = 0.408$; $X_{10} = 0.276$

Substituting above optimal values, maximum production rate is given by,

$Y_1 = 1.154651 - 6.2E\text{-}05\times210 + 0.000347\times25 - 0.00445\times1 - 0.00196\times0 - 0.02525\times40 + 0.028952\times36 - 0.00284\times98.10 + 1.165921\times0.58 + 0.27392\times0.408X_9 + 3.523711\times0.276$

The maximum production rate is,

$Y_1 = 2.66$ slices/sec.

VIII. CONCLUSION

The set up is developed for experimentation. The readings are tabulated in a proper format. The ANN validation is carried with the help of MATLAB for production rate, quality and efficiency.

The mathematical model is developed by multivariable linear regression model for production rate.

The optimization is carried out by using range bound method for production rate. The maximum production rate is found to be 2. 66 slices/sec.

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