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Prediction of Specific Wear rate of Glass Filled PTFE Composites by Artificial Neural Networks and Taguchi Approach

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ABSTRACT

Polymeric materials such as Polytetra-fluoroethylene (PTFE) is widely used as a bearing material and mechanical seals due to its unique properties such excellent chemical resistance, low coefficient of friction and high-temperature stability. In the present work attention is focused on Sp.Wear rate of PTFE with glass reinforcement with the percentage of 15,25 and 35 at Velocity 0.5,1 and 2 m/s ,Load 15.696,25.506 and 35.316 N,Time 30,60 and 60 minutes by using a pin-on-disc Tribometer (TR–20)in Dry Condition . From a Taguchi approach orthogonal array, L-27 is selected as per three parameters and three levels to carry out the experiment. Regression analysis is done to get correlation between sliding speed, load and sliding time and to predict the wear rate. As per results applied load is the parameter that has the highest statistical influence on the sliding wear. The artificial neural network was applied to predict Sp.Wear rate Glass Filled PTFE Composites. Based on a measured database of PTFE composites, wear is successfully calculated through a well-trained artificial neural network which is carried out in MATLAB R2009a software. The quality of Prediction was good when compared with tested values.

Keywords: Artificial Neural Network (ANN) friction, Polymer composite, wear

1 INTRODUCTION

It is necessary to develop and test the new composite material for tribological application which is complex Process. In development of new composite material it is necessary to understand the composition, manufacturing process and operating parameter. To study the tribological properties of Polymer like PTFE is time consuming process and complicated which includes lots of iteration between operating parameters and compositions. ANN modeling is feasible solution for this which can use experimental data even though it is noisy and complex to predict the material Properties. This ANN network which is inspired from the Biological nerve system can learn from Experience and find the solution. In the present work ANN with Back propagation algorithm (BP) is used to predict the tribological properties of PTFE material under different conditions and compositions.

2 ARTIFICIAL NEURAL NEWORK APPROACH

An ANN structure having three layers input layer, hidden layer and output layers as shown in fig 1. An artificial neuron is a device with many inputs and one output. The neuron has two modes of operation; the training mode and the using mode. In the training mode, the neuron can be trained to fire (or not), for particular input patterns. In the using mode, when a taught input pattern is detected at the input, its associated output becomes the current output. If the input pattern does not belong in the taught list of input patterns, the firing rule is used to determine whether to fire or not.

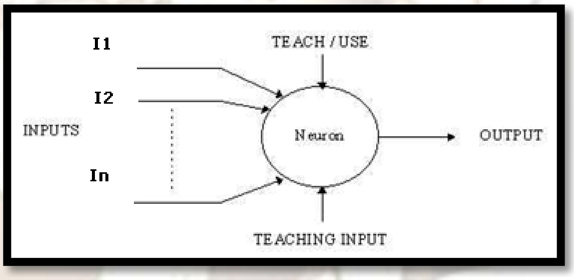

Fig.1 Basic model of Artificial Neuron

The structure of neural network can be expressed as N_{in}-[N_i- N_{ii}- N_{iii}-------- N_n] $_n$-N_{out} where N_{in} and N_{out} is number of inputs and outputs variables. Subscript n indicates number of Hidden layers. N_i, N_{ii} and N_n are the number of neuron in each hidden layer. Hidden layers process the input data which is getting from Input layers and export the results via output layer. Each neuron takes the output of the neuron in the preceding layers. Output can be described by,

$$X_j^{(n)} = f[\Sigma\, W_{ji}^{(n)} X_i^{(n-1)} + b_j^{(n)}] \quad \text{------------------------- (1)}$$

Where $X_j^{(n)}$ is the output of node j in the n^{th} layer, $W_{ji}^{(n)}$ is the weight from the node i in the $(n-1)^{th}$ layer to the node j in n^{th} layer. $b_j^{(n)}$ is the bias of node j in the nth layer. In this study tan sigmoid function is used.

$$f(x)=[1-e^{-2x}]/[1+e^{-2x}] \quad \text{----------------------------------(2)}$$

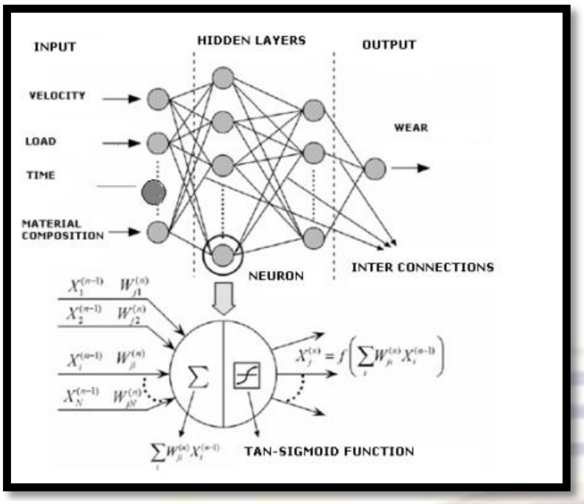

Fig.2 A schematic illustration of an artificial neural network

BP algorithm is used to minimize the mean square error between predicted and desired values. It is iterative gradient descent approach. [1]

$E=[1\backslash 2L]\{\Sigma\ [d(t)-p(t)]^2\ \}$ where $1\leq\ t \leq L$ ----(3)

L is number of training patterns, d (t) is desired output and p (t) is target output predicted by ANN

3. EXPERIMENATAL

3.1 Testing Procedure

A disc (Ø 160mm×10 mm) rotating at a selected speed slid against a pin (Ø 10mm×20 mm).According to velocity track diameter of pin on disc was varied accordingly. En8 discs and pin were polished with metallographic abrasive papers (C-400) and (C-600) respectively. This pre-rubbing process ensured a full contact of the pin and disc surfaces. The surface roughness Ra of polymer specimens was 0.09–0.11μm. All the specimens were manually cleaned in petrol and then thoroughly dried. The friction and wear tests were performed at room temperature (28 ^{0}C) in atmosphere. Applied loads ranged from 15.696N to 35.316N and rotation speeds of discs ranged from 0.5m/s to 2m/s, time ranged from 30 to 90 minute, and the sliding distance was varied accordingly[2].

Table 1 Testing parameters

Sr. No	Velocity (m/s)	Load (N)	Time (min)	GF (%)
1	V1=0.5	L1= 15.696	T1=30	M1=15
2	V2=1	L2= 25.506	T2=60	M2=25
3	V3=2	L3= 35.316	T3=90	M3=35

In the present work Taguchi method used as Design of Experiment which gives 27 wear experiments (L_{27} orthogonal Array) which were performed at various operating parameters and with different compositions (Table 1) by using Pin on Disc Tribometer (TR-20).

The experiment consists of 27 tests as shown in table 2.Column were assign to the parameters. The first column was assign to the sliding velocity, second column was assigned to load , fifth column was assigned to sliding time and the ninth column was assigned to weight percentage reinforcement and the remaining columns were assigned to their interactions. The response to be studied was the wear with the objective as smaller, as the better. The experiments were conducted as per the orthogonal array with level of parameters given in each array row [3]

3.1 Specifications of Tribometer (TR-20)

- Pin Size:3 to 12 mm Diagonal
- Disc Size:160 mm dia. X 8 mm thick
- Wear Track Diameter: 10- 140 mm
- Sliding Speed Range: 0.26-10 m/sec.
- Disc Rotation Speed:100-2000 RPM
- Normal Load: 200 N (maximum).
- Friction Force:0-200 N, digital readout, recorder output
- Wear Measurement Range:4 mm, digital readout, and recorder output
- Power 230 V, 15A, 1 Phase, 50 Hz

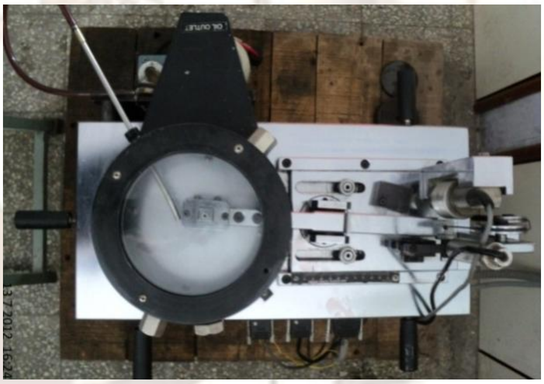

Fig.3.a Experimental set up

Fig.3.b Control Panel of Experimental set up

Table 2 L_{27} Orthogonal Array of Taguchi.

L_{27}	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	2	2	2	2	2	2	2	2	2
3	1	1	1	1	3	3	3	3	3	3	3	3	3
4	1	2	2	2	1	1	1	2	2	2	3	3	3
5	1	2	2	2	2	2	2	3	3	3	1	1	1
6	1	2	2	2	3	3	3	1	1	1	2	2	2
7	1	3	3	3	1	1	1	3	3	3	2	2	2
8	1	3	3	3	2	2	2	1	1	1	3	3	3
9	1	3	3	3	3	3	3	2	2	2	1	1	1
10	2	1	2	3	1	2	3	1	2	3	1	2	3
11	2	1	2	3	2	3	1	2	3	1	2	3	1
12	2	1	2	3	3	1	2	3	1	2	3	1	2
13	2	2	3	1	1	2	3	2	3	1	3	1	2
14	2	2	3	1	2	3	1	3	1	2	1	2	3
15	2	2	3	1	3	1	2	1	2	3	2	3	1
16	2	3	1	2	1	2	3	3	1	2	2	3	1
17	2	3	1	2	2	3	1	1	2	3	3	1	2
18	2	3	1	2	3	1	2	2	3	1	1	2	3
19	3	1	3	2	1	3	2	1	3	2	1	3	2
20	3	1	3	2	2	1	3	2	1	3	2	1	3
21	3	1	3	2	3	2	1	3	2	1	3	2	1
22	3	2	1	3	1	3	2	2	1	3	3	2	1
23	3	2	1	3	2	1	3	3	2	1	1	3	2
24	3	2	1	3	3	2	1	1	3	2	2	1	3
25	3	3	2	1	1	3	2	3	2	1	2	1	3
26	3	3	2	1	2	1	3	1	3	2	3	2	1
27	3	3	2	1	3	2	1	2	1	3	1	3	2

4. TRAINING AND VERIFYING

The ANN program were written in MATLAB 2009a.The experimental database was divided into two parts i.e. one for training and other for testing the ANN. The artificial neural network achieved a stable state after 100 cycles of training and the mean square error of network reach 0.01.The verifying result is as show in fig.3. For relieving the training difficulty and to balance the effect of the each parameter on output the experimental data was normalized.

Back-propagation (BP) algorithm is an iterative gradient descent approach. It is one of the most widely used training algorithms for multi-layer networks, to minimize the mean squared error E between the predicted and desired values. In this work Feed Forward back propagation network was used. Number of layers and neurons was 3 and 20 respectively. Activation functions Logarithmic Sigmoid for 1st and 2nd layers, Linear for 3rd layer was used. Training algorithm Trainbr- back propagation with supervised training method was used. After training this Experimental Data its Weight which is generated by Software used for Prediction of Wear for Different input parameters with different Combinations [4].

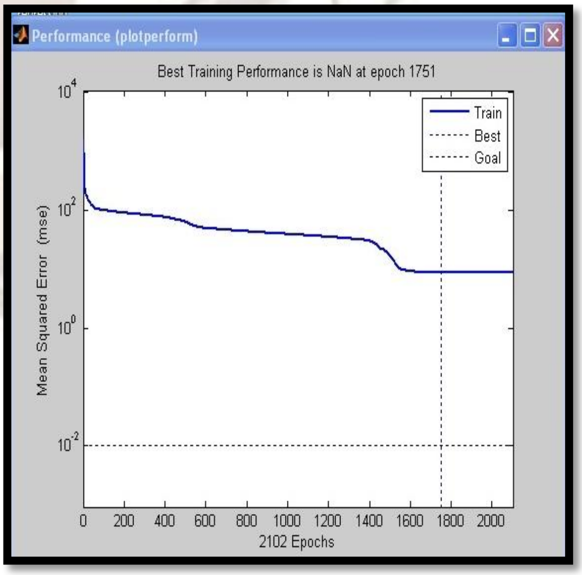

Fig 3.The error curve of training.

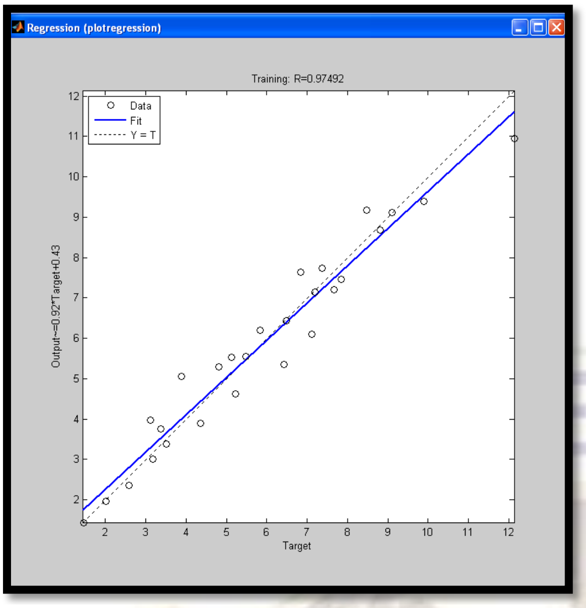

Fig 4.Verifying result of wear with BP neural network.

4. PREDICTION AND DISSCUSSION

4.1 Influence of operating parameters on Tribological behavior

The relation between predicted values from the trained network and tested data as shown in fig 5.

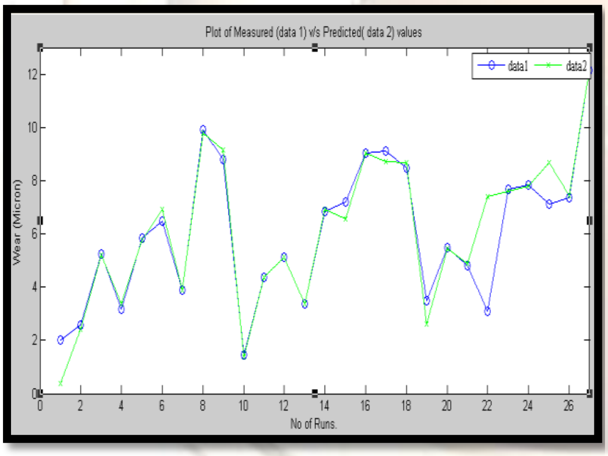

Fig 5.Plot of measured value v/s Predicted Values.

Sp.Wear rate (mm3/Nm) is decrease with increasing speed while there is very less variation in case of increase of Load. (Fig 6).From the graph it is clear that, initially coefficient of friction increases, but after certain time it remains almost constant or increases slightly. (Fig 7).At lower load the coefficient of friction increase with increase in load after some time it may deceases with increase in applied load.

Specific wear rate of PTFE material M3 is less as compared to the other PTFE materials M1 & M2.Therefore Material M3 is best material than material M1 &M2 due to higher load caring capacity with more Glass Fiber percentage. From this result we can say that Wear resistance of PTFE composite material increases with increases in percentage of GF.

Optimum response as a minimum wear the operating parameter should be V1L1T1M2 that is when sliding take place between PTFE with 25% GF material at sliding speed 0.5 m/s, load 15.75 N and sliding time 30 min. wear will be minimum in dry condition which can be observe from predicted values of ANN.

Table 3 Tested data, predicted data by BP Network and Error.

No of Run	Measured Values	Predicted Values	Relative Error
1	2.01	0.39	1.62
2	2.58	2.40	0.18
3	5.23	5.21	0.02
4	3.18	3.37	-0.19
5	5.83	5.76	0.07
6	6.49	6.90	-0.41
7	3.89	3.88	0.01
8	9.90	9.81	0.09
9	8.81	9.16	-0.35
10	1.46	1.38	0.08
11	4.35	4.39	-0.04
12	5.12	5.11	0.01
13	3.38	3.38	0.00
14	6.83	6.91	-0.08
15	7.20	6.55	0.65
16	9.05	9.02	0.03
17	9.10	8.73	0.37
18	8.47	8.66	-0.19
19	3.50	2.60	0.90
20	5.47	5.44	0.03
21	4.81	4.89	-0.08
22	3.11	7.39	-4.28
23	7.66	7.58	0.08
24	7.84	7.78	0.06
25	7.11	8.66	-1.55
26	7.37	7.44	-0.07
27	12.13	12.15	-0.02

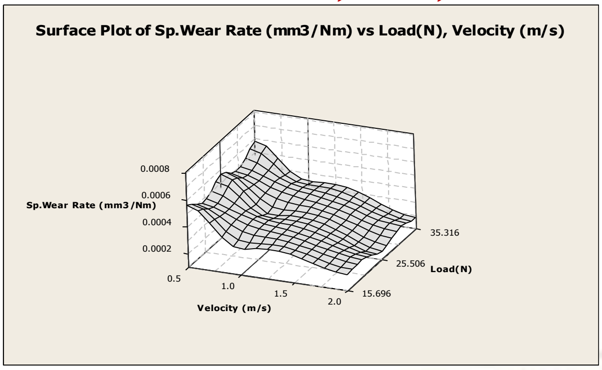

Fig 6. ANN predicted 3D profiles of the specific wear rate friction coefficient as function of the sliding speed and applied Load

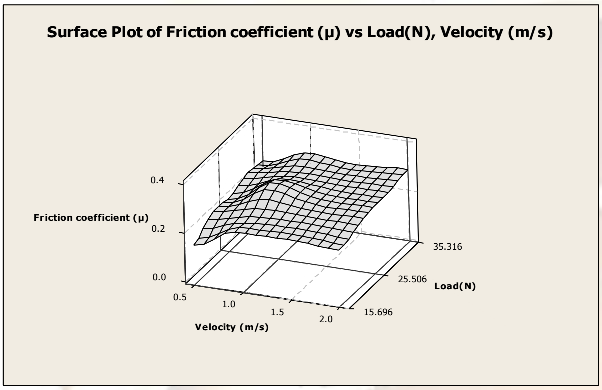

Fig 7. ANN predicted 3D profiles of the friction coefficient as function of the sliding speed and applied Load.

5. CONCLUSION

1. In the present work for studying wear and friction properties of Glass filled PTFE composites ANN approach was applied. The prediction accuracy was satisfactory but it will depend on number of training data. This means without continuing further testing we can predict the result hence saving time and cost which could be the useful to industry to build the more general and particular databases of Material Properties.

The prediction quality can be improved if the database for training process is enlarged or the Configuration of network could be further optimized by using number of training function. A simple structure of hidden layer including several neurons has an adequate capability to model the problems. However, some complex relationships, like specific wear rate in this work, require a more complex network structure. The prediction quality increases in a certain rage with an increase in neurons, but it deteriorates when the neuron number exceeds the saturation value.

2. Minimum wear will be when sliding take place between PTFE with 25% GF material at sliding speed 0.5 m/s, load 15.75 N and sliding time 30 min. wear will be minimum in dry condition which can be observe from predicted values of ANN.

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