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Use of Artificial Neural Networks to Investigate the Surface Roughness in CNC Milling Machine

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Abstract: ***In order to sustain in the global market competitiveness, maintaining the quality of the component plays a key role to satisfy the customer requirements. Quality can be determined by its surface roughness or by its surface finish. In this work, optimization of machine tool parameters is carried out for CNC milling machine. Machine tools can be used effectively by considering the optimal cutting parameters like speed, feed, and depth of cut. However these parameters greatly influence on the material removal rate and surface finish. This paper aims to investigate the surface roughness values at various speeds, feed and depth of cut conditions by using Artificial Neural Networks. ANN results show that there is no significant difference between the experimental values and predicted roughness values. From these results, conclude that the ANN is best suitable and accurate for solving the cutting parameter optimization.***

Keywords: CNC Milling process, Optimization, Surface roughness, Artificial Neural Networks (ANN).

1. Introduction

There is a tremendous increase in demand for manufacturing the precise components, surface finish [6] plays an important role and also it helps in producing best quality of the products to satisfy the demands from the customers and thereby to increase profitability for an organization. Reduction in surface roughness [8] increases good fatigue strength, corrosion resistance, reduction in friction, avoids wear and tear of the material, also helps in ability to withstand at high loads, where as high roughness causes formation of the cracks in the component when it is subjected to sudden loads or at high static loads due to formation of these cracks may yields to failure of the component. In order to avoid this failure in the component better surface finish should be maintained by reducing the roughness factor while manufacturing the component itself. There are some of the machining parameters greatly influence on the better surface finish like feed, depth of cut, spindle speed, selection of machine tool, type of tool holder, input power, machining time, and cutting speed [7] . In this work, to optimize [2] and predict [1,5] the values of the machining process, feed, speed and depth of cut were taken as inputs and roughness is taken as target to the Artificial Neural Networks (ANN).

1.1 Artificial Neural Networks

The concept of neurons is the fundamental constituent of the brain. Brain contains 10^{10} basic units called neurons. Each neuron connected to 10^4 other neurons.

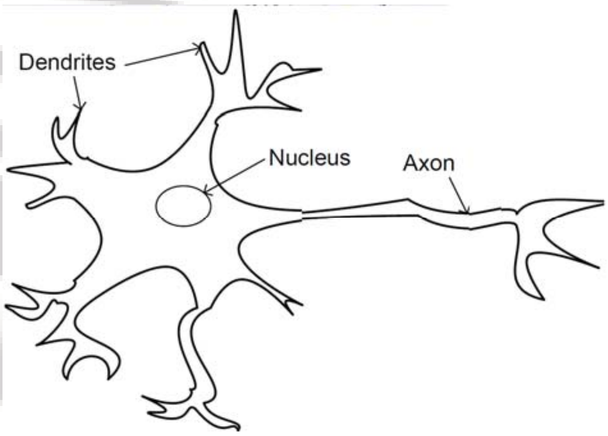

Figure 1: Biological Neuron

A neuron is composed of a nucleus, it is a cell body called as soma, attached to this cell body consists of large irregularly shaped filaments called dendrites; these behave like as input channels. All inputs from other neurons arrive through this dendrite like structure. In details dendrites look like branches of tree. Another type of link attached to the soma is the Axon, serves as the output channel.

1.2 Model of an Artificial Neural Network

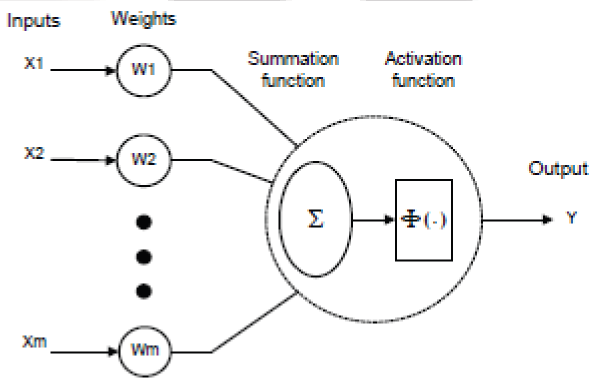

Figure 2: Simple model of an Artificial Neuron

The above figure shows the simple model of an artificial neuron system that can imitates the biological actual neuron system. Every component of the model bears a direct analogy to the actual constitutes of a biological neuron and hence it termed as artificial neuron. In this model which performs the basis of Artificial Neural Networks. Here x_1, x_2,...., x_m are the n inputs to the artificial neuron. w_1, w_2,...., w_m are the weights attached to the input links. The biological neuron receives all inputs through the dendrites, sums them and produces an output, if the sum is greater than a threshold value. The input signals are passed on to the cell body. Total input I is received by the soma of the artificial neuron is

$$I = w_1x_1 + w_2x_2 + \ldots\ldots\ldots\ldots + w_nx_n$$
$$= \sum_{i=1}^{n} w_i x_i$$

To generate the final output y, the sum is passed on to a non-linear filter called Activation function which releases the output y.

$$Y = \phi\,(I)$$

A very commonly used Activation function is the Threshold function. In this, the sum is compared with a threshold value θ. If the value *I* is greater than θ, then the output is 1 else it is 0. The function is continuous function that varies gradually between the asymptotic values 0 and 1 or -1 and +1 and is given by

$$\phi\,(I) = \frac{1}{1 + e^{-\alpha I}}$$

Where α is the slope parameter, adjusts the function as it changes between two asymptotic values 0 and 1 or -1 and +1.

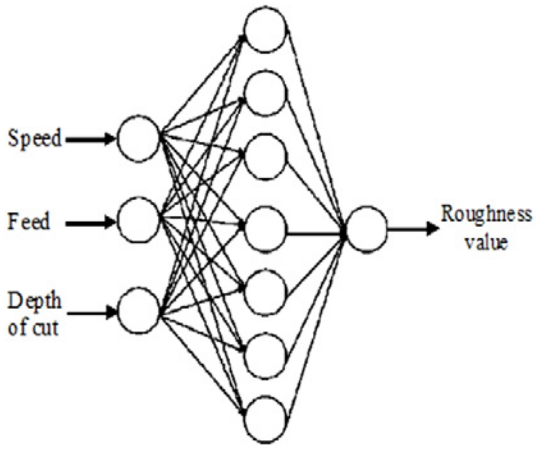

Figure 3: Simple model of Artificial Neural Network

In this paper, i used Lavenberg-Marquard feed forward back propagation algorithm to train and simulate the network. Neural networks with back propagation algorithm were used to derive the models for time-varying positioning error tracking. It is a supervised learning scheme by which a layered feed forward network with continuously valued processing elements is trained for nonlinear pattern mapping. The difference between the target value and network output propagates backward during training to modify the weights so that the network can produce the matching output pattern when the corresponding input pattern is given. Feed forward back propagation network uses feed forward neuron connections and is trained with supervised back propagation learning rule. Network is trained by providing it with input data (Speed, Feed, and Depth of cut) and the corresponding output data (Experimental roughness data). The biases and weights of the network are modified to minimize error. The network used here containing of two hidden layers containing ten hidden neurons with log-sigmoid transfer activation functions.75% of the data is used for training the network and remaining 25% is used for validating the network to unlearned inputs.

Characteristics of Neural Networks:

1) The neural networks exhibit mapping capabilities, that is, they can map input patterns to their output patterns.
2) The neural networks learn by examples. Thus, neural networks architecture can be trained with known examples of a problem before they are tested for their interface capability on unknown instances of the problem. They can, therefore, identify new objects previously untrained.
3) The neural networks possess the capability to generalize. Thus they can predict new outcomes from past trends.
4) The neural networks are robust systems and are fault tolerant. They can, therefore, recall full patterns from incomplete, partial or noisy patterns.
5) The neural networks can process information in parallel, at high speed, and in a distributed manner.

2. Methodology

In this paper, experiments are conducted with MTAB XLMILL machine to investigate the roughness values at various machining parameters (Speed, Feed and Depth of cut).

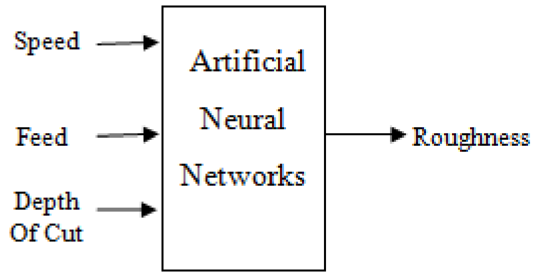

Figure 4: Schematic diagram of ANN for Machining parameters and roughness.

The above schematic diagram represents the method of investigation of roughness values at various machining parameters using Artificial Intelligence techniques [4]. In this paper, proposed methodology is Artificial Neural Network (ANN), it can be used to find, optimize [3] and predict roughness parameters. Here, ANN uses Feed-forward back propagation networking with Lavenberg-Marquard algorithm to train and simulate the network. The network is trained with two hidden layers each containing ten neurons. With the given input values (Machining parameters) and output values (Roughness) were obtained from the experimental data as shown below in Table.1, the network is trained with Lavenberg-Marquard algorithm and it is simulated with feed-forward back propagation network [5,6] with unknown input machining parameters. Table.1 represents the experimental values and actual roughness readings. These readings are trained with Lavenberg-Marquard algorithm by using Artificial Neural Networks in the MAT LAB 7.8 software. The regression value (R) for training, validation and testing data obtained in the form of MATLAB graphs. Performance of the training data is measured in terms of accurate fitness obtained from the MATLAB results in the form of graphs. The network is trained with two hidden layers and ten hidden neurons, best training regression value obtained from results is R=0.99994 as shown in figure.5.

Table 1: Training the data

Exp No	Speed (rpm)	Depth of Cut (mm)	Feed Rate (mm/rev)	Roughness (µm)
1	1700	1.2	0.15	0.7935
2	1700	1.5	0.2	0.8450
3	1700	1.9	0.2	0.9460
4	1850	2.1	0.3	1.1522
5	1850	2.2	0.4	1.4465
6	1850	2.5	0.6	0.9964
7	2000	2.8	0.35	1.0060
8	2000	3.0	0.7	1.0964
9	2000	3.5	1.0	1.2657
10	2300	3.5	1.2	1.4560
11	2300	3.8	1.5	1.1200
12	2300	4.0	0.8	0.8563
13	2750	4.2	1.3	1.0003
14	2750	4.5	1.5	1.3265
15	3000	4.7	0.7	0.8329
16	3000	4.9	1.3	1.2300
17	3000	5.2	0.3	0.8463
18	3300	5.5	1.2	1.0764
19	3300	5.5	1.5	1.1659
20	3300	5.7	1.7	1.2193
21	3500	5.7	1.1	1.0280
22	3500	5.8	0.9	1.0196
23	3500	6.0	0.8	1.0010

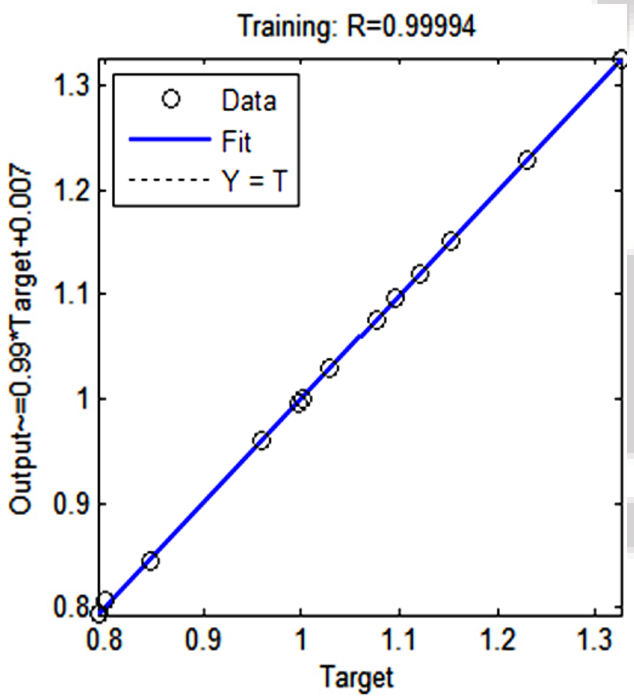

Figure 5: Regression Training Results

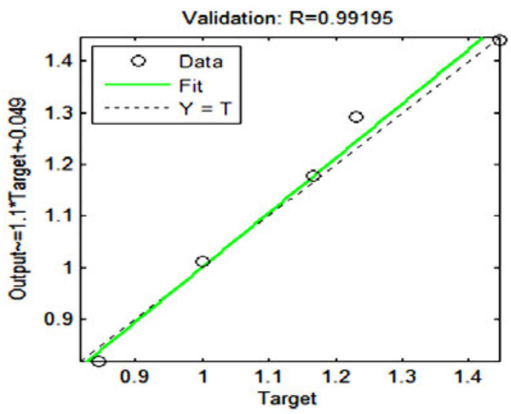

Figure 6: Regression validation Results

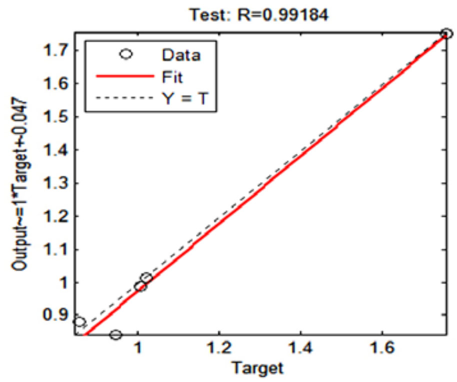

Figure 7: Regression of Test Results

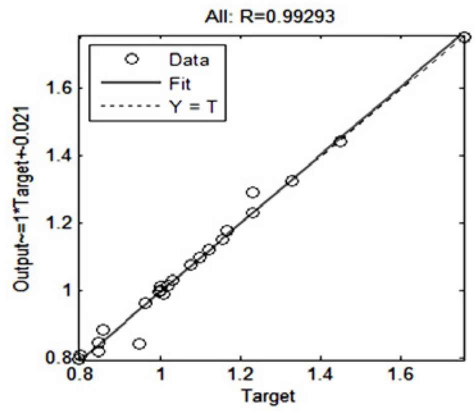

Figure 8: Regression of overall results

From all these graphs, best regression value for validating the data is R=0.99195 as shown in figure.6, regression value for testing the data is R=0.99184 as shown in figure.7 and overall regression value is R=0.99293 as shown in figure.8. Form all these training sets, it shows that the values are in the range of 0 to 1 of log sigmoid transfer function, obtained overall regression value is 0.99184 which is approximately equal to 1 i.e., maximum value of transfer function thus we can say that the network is trained well.

3. Testing the Data

The data can be tested with unknown input data using feed-forward back propagation algorithm to predict the roughness values as shown in the Table.2. The best validation performance is obtained at epoch 0 and mean squared error (mse) for testing the data is 0.0003807 as shown in figure.9, this value is obtained when the network is tested with two hidden neurons and two hidden layers with log sigmoid transfer function using back propagation algorithm.

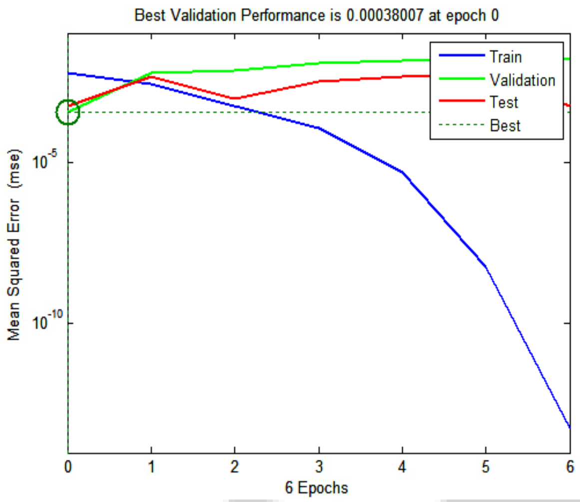

Figure 9: Evaluation of mean squared error

Table 2: Testing the Data

Exp No	Speed (rpm)	Depth of Cut (mm)	Feed Rate (mm/rev)	Predicted Roughness (μm)
1	1800	1.9	0.25	0.7936
2	1900	2.7	0.38	1.0804
3	2200	3.6	0.5	1.2011
4	2600	4.8	0.7	1.2659
5	3400	3.2	0.3	0.7364

4. Results and Discussions

The actual roughness values and the same are compared with predicted roughness values obtained from Mat lab 7.8 software. The percentage of deviation between predicted and actual values have been calculated and tabulated. From these we can found that predicted values are very nearer to actual readings. Machining parameters are greatly influence on surface roughness.

Table 3: Comparison of Predicted & Actual roughness values

Exp No.	Speed (rpm)	Depth of Cut(mm)	Feed Rate(mm/rev)	Actual Roughness(μm)	Predicted Roughness(μm)	Difference	%of Deviation
1	1800	1.9	0.25	0.8247	0.7936	0.0311	3.771068
2	1900	2.7	0.38	1.2900	1.0804	0.2096	16.2480620
3	2200	3.6	0.5	1.3180	1.2011	0.1169	8.8694992
4	2600	4.8	0.7	1.3560	1.2659	0.0901	6.6445427
5	3400	3.2	0.3	0.7698	0.7541	0.0157	2.0394907
Average % of Deviation 7.51453252							

5. Conclusion

From all these results, it is evident to say that roughness value is depends on the machining parameters like speed, feed rate and depth of cut. In this work, artificial neural networking method is used to investigate and optimize the experimental procedure. Surface roughness value, when the experiments are conducted with the different combination of speed, depth of cut and feed rate (3000, 4.7, 0.7) is 0.8329, (1800, 1.9, 0.25) is 0.8247, (1700, 1.2, 0.15) is 0.7935, and (3400, 3.2, 0.3) is 0.7698. From these combination data sets, Surface roughness is reduces at maximum speeds and at minimum feed rate. If the feed rate is high the surface finish reduces there by surface roughness increases. The experimental data is predicted, investigated and optimized by using the Artificial Neural Networks with the help of Mat lab software. Deviation between the Actual readings and predicted readings is calculated, average percentage of deviation is very low i.e., 7.51453252. From this, it is evident to say that the predicted readings and actual readings are nearly equal.

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