***BALKANTRIB'O5***
***5th INTERNATIONAL CONFERENCE ON TRIBOLOGY***
***JUNE.15-18. 2005***
**Kragujevac, Serbia and Montenegro**

# NEURAL NETWORK PREDICTION OF SURFACE ROUGHNESS IN MILLING OF AISI 1040 STEEL

*E.S TOPAL, C. SİNANOĞLU*, E. GERÇEKCİOĞLU, K. YILDIZLI*

*Mechanical Engineering Department, Engineering Faculty,*

*Erciyes University, 38039 Kayseri-TURKEY*

*The aim of this study is to predict surface roughness in end milling of AISI140 steel. In realising this, machining experiments are performed under various cutting conditions by using sample specimens. The surface roughnesses of these specimens are measured. A Neuron Network model is employed for predicting surface roughness. This approach provides to predict the experimental surface roughness in end milling of AISI1040 Steel.*

**Key words:** *Surface Roughness, Milling, Neural Nets*

## 1. INTRODUCTIONS

Surface roughness is a criterion of the product quality of machined parts and a factor that greatly influences tribological characteristics of a part (i.e. friction and wear behaviour). Several factors will influence the final surface roughness in a CNC milling operation. The final surface roughness might be considered as the sum of two independent effects:

1) the ideal surface roughness is a result of the geometry of tool and feed rate and

2) the natural surface roughness is a result of the irregularities in the cutting operation [1].

Factors such as spindle speed, feed rate, and depth of cut that control the cutting operation can be setup in advance. However, factors such as tool geometry, tool wear, chip loads and chip formations, or the material properties of both tool and workpiece are uncontrolled. Even in the occurrence of chatter or vibrations of the machine tool, defects in the structure of the work material, wear of tool, or irregularities of chip formation contribute to the surface damage in practice during machining. One should develop techniques to predict the surface roughness of a product before milling in order to evaluate the fitness of machining parameters such as feed rate or spindle speed for keeping a desired surface roughness and increasing product quality. It is also important that the prediction technique should be accurate, reliable, low-cost, and non-destructive. Therefore, the purpose of this study is to develop one surface prediction technique which is termed the multiple regression prediction model and then evaluate its prediction ability [2].

Surface finish could be specified in many different parameters. Due to the need for different parameters in a wide variety of machining operations, a large number of newly developed surface roughness parameters were developed. Some of the popular parameters of surface finish specification are described as follows:

• Roughness average (Ra): This parameter is also known as the arithmetic mean roughness value, AA (arithmetic average) or CLA (centre line average). Ra is universally recognized and the most used international parameter of roughness. Therefore,

$$R_a = \frac{1}{L}\int_0^L |Y(x)|dx \qquad (1)$$

where Ra = the arithmetic average deviation from the mean line

L : the sampling length

Y : the ordinate of the profile It is the arithmetic mean of the departure of the roughness profile from the mean line.

• Root-mean-square (rms) roughness (R*q*): This is the root-mean-square parameter corresponding to R*a*:

$$R_q = \sqrt{\left[\frac{1}{L}\int_0^L (Y(x))^2 dx\right]} \qquad (2)$$

• Maximum peak-to-valley roughness height (R*y* or R*max*): This is the distance between two lines parallel to the mean line that contacts the extreme upper and lower points on the profile within the roughness sampling length. Since Ra and Rq are the most widely used surface parameters in industry, $R_a$ was selected to express the surface roughness in this study.

## 2. EXPERIMENTAL STUDY

Experiments were realised using a TAKSAN TMC 500 Vertical Machining Centre. Machining parameters used in the experiments are presented in Table 1. Sample workpieces were cut from extruded AISI 1040 steel bar with dimensions 10x50x100 [mm]. A pre-machining with mild cutting conditions is done on the specimens on account of obtaining a uniform surface at initial. TiAlN plated carbide end milling tool is used. The surface roughness ($R_a$) was measured in micro meter [μm] by a Mitutoyo profilometer. The measured $R_a$ values are also shown in Table 1.

## 3. ARTIFICIAL NEURAL NETWORKS

Artificial NN are non-linear mapping systems with a structure loosely based on principles observed in biological nervous systems. In the most general terms, a NN consist of large number of simple processors linked by weighted connections. It has many inputs (in) and one output (out). The connections between neurons are realised in the synapses (Figure 2).

- inputs $x_1, x_2, .....x_n$
- weights, bound to the inputs $w_1 w_2, ...w_n$
- an input function $(f)$, which calculates the aggregated net input
- signal U to the neuron (this is usually a summation function)
- an activation (signal) function, which calculates the activation
- level of the neuron: $O = g(U)$

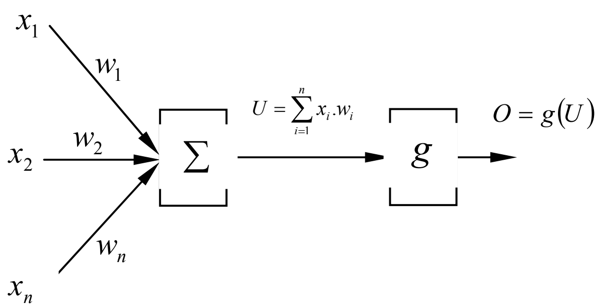


**Figure 1:** *The artificial neuron model*

A network is trained so that application of set inputs produces the desired (or at least consistent) set of outputs. Each such input (or output) set is referred to as a vector. Training is accomplished by sequentially applying input vectors, while adjusting network weights according to a predetermined procedure.

During training, the network weights gradually converge to values such that each input vector produces the desired output vector.

The neural network was trained with Quick propagation algorithm [3]. The activation (transfer) functions are possible for each hidden layer and the output layer. In this study, the tanh function [4] is used to hidden layers and output layers as an activation function. Linear function [5] is taken for input layer.

## 4. SIMULATION AND EXPERIMENTAL RESULTS

The machined specimens were measured with a profilometer to obtain the average roughness value $R_a$. The samples were randomly divided into two data groups- the training group and the testing group. The training group consisted of 30 samples which were used to obtain a model and the testing group consisted of 10 samples which were used to test the appropriateness of the neuron model.

A prediction model was created by neuron model which described in Section 3 from the training data group. The structural and training parameters of the proposed network are given in Table 2. Moreover, an average Rms error for used training algorithm is 0.041.

**Table 2. The structural and training parameters**

| | $\eta_l$ | $\mu$ | $N$ | $n_I$ | $n_H$ | $n_O$ | $AF$ |
|---|---|---|---|---|---|---|---|
| ***Cases*** | 0.1 | 0 | 50000 | 3 | 10 | 1 | tanh |

According to Figure 2, in all cases, neural network predictor, which is consisted of three input neurone, ten hidden layer neurones, one output neuron with (tanh) non-linear activation function, has a good performance to predict average roughness with a wide range of machining conditions.

In Figure 2.a, test with S=1500 rev/min, a=0.25 mm and varying feed rate between 100-500 mm/min, the average roughness $R_a$ increases slightly. The neural network model predicts experimental variations with a negligible error. The same trend is also valid in the Figure 2.c

It was also apparent that spindle speed was the most significant machining parameter to influence surface roughness.

The error convergence graphs of all cases are depicted in Figure 3 during the training of the network and the error histogram is shown in Figure 4.

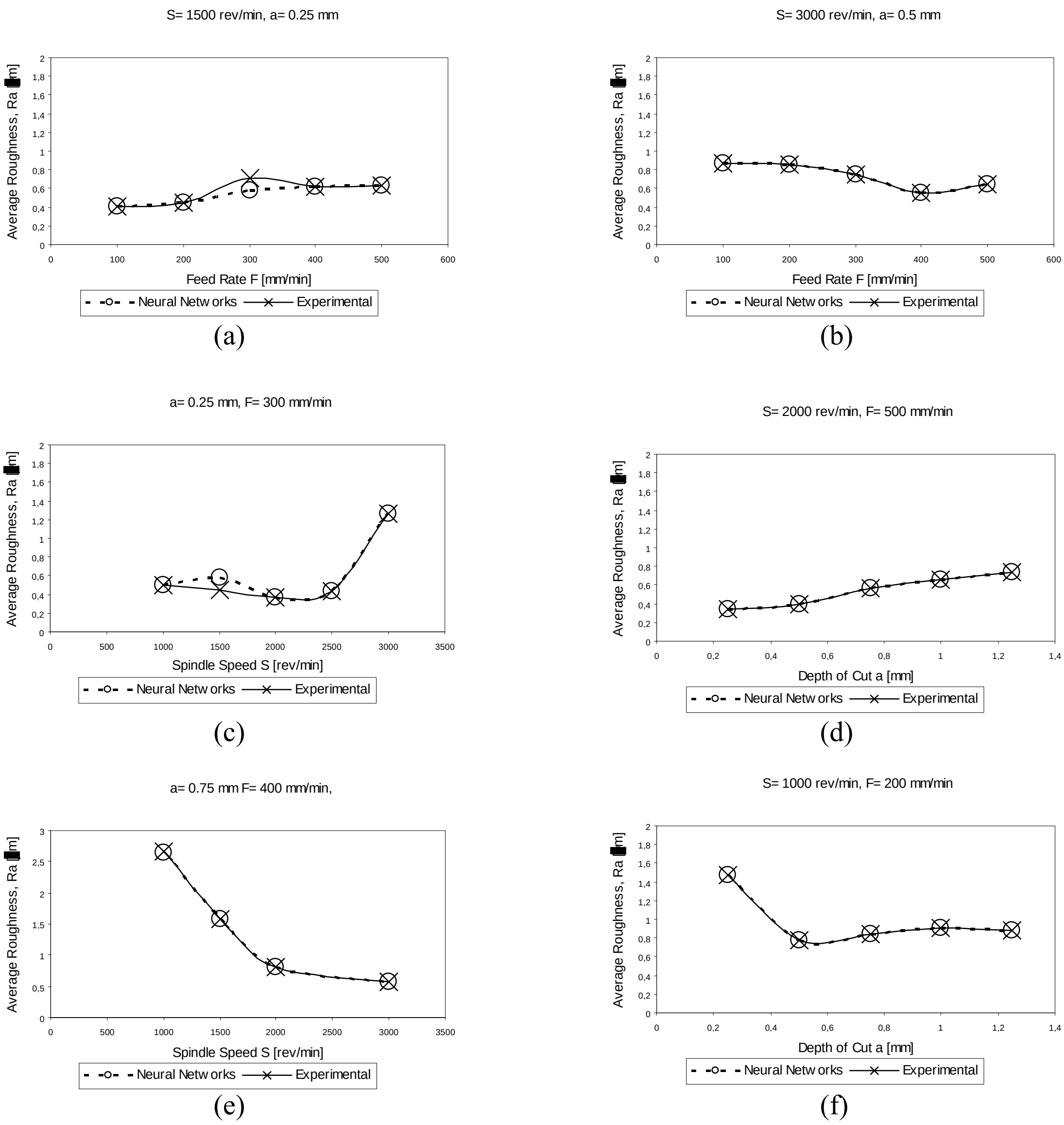


**Figure 2:** *Experimental and Simulational results*

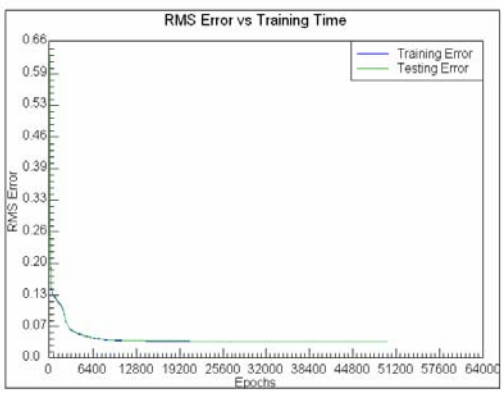


**Figure 3:** *Rms error for training and testing data*

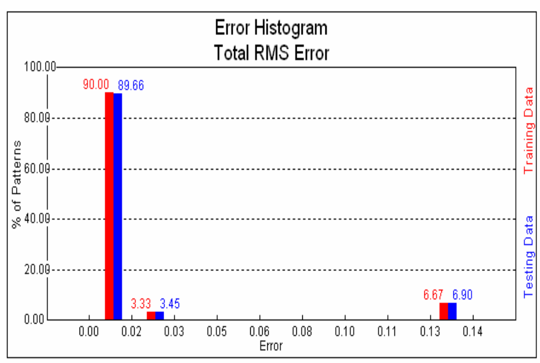


**Figure 4:** *Error histogram for experiments*

## 5. CONCLUSION

The surface roughness deviations of AISI 1040 steel is examined. Through experimentation, the system proved capable of predicting the surface roughness with about 96 % accuracy. The important conclusion yielded from the present study can be expressed as follows:

- The surface roughness could be predicted effectively by applying spindle speed, feed rate, depth of cut and their interactions in the Neural Network Model.

- The spindle speed was the most significant machining parameter used to predict the average surface roughness in the Neural Network Model.

## 6. REFERENCES


[1] Bouthroyd, G. and W. A. Knight, "Fundementals of Machining and Machine Tools", Second Edition, Marcell Dekker Inc., New York, 1989

[2] Lou, M. S. et all "Surface Roughness Prediction Technique for CNC End-Milling" Journal of Industrial Technology, V15 (1) 1999

[3] Sinanoğlu, C., Kurban, A.O., Yıldırım, Ş. (2004), Analysis of Pressure Variations on Journal Bearing System Using Artificial Neural Network, Industrial Lubrication and Tribology, Vol. 56 No. 2, pp. 74-87

[4] Bharath, R., Drosen, J., Neural Network Computing, Windcrest /Mc. Graw-Hill, 1994.

[5] Canbulut, F., Yıldırım, Ş. and Sinanoğlu, C. (2004), Design of An Artificial Neural Network for Analysis of Frictional Power Loss of Hydrostatic Slipper Bearings, STLE Tribology Letters, Vol. 17 No. 4, pp. 997-899.