Scientific Journal of Impact Factor (SJIF): 5.71
e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406
International Journal of Advance Engineering and Research Development
Volume 5, Issue 03, March -2018

Investigation of the effect of process parameters on the surface roughness of AISI 1040 steel in CNC turning – ANFIS modeling

Sunny V. Patel[1],Kiran A. Patel[2]

[1]*M.E. (Production Engineering) student, Mechanical Engineering Department, LDRP-ITR,Gandhinagar, Gujarat, India*
[2]*Asst. Professor, Mechanical Engineering Department, LDRP-ITR, Gandhinagar, Gujarat, India*

Abstract —*Many manufacturing industries involve machining operations. In metal cutting the turning process is one of the most fundamental cutting processes used. Surface finish and dimensional tolerance, are used to determine and evaluate the quality of a product, and are major quality attributes of a turned product. In this paper, an attempt has been made to investigate the effect of cutting parameters cutting speed, feed rate and depth of cut on surface roughness. The turning operation is carried out on CNC Machine and the workpiece material used is AISI 1040 Steel. First of all trial experiments are carried out to decide the levels of different parameters and then L27 orthogonal array has been used for experiments. ANFIS (Adaptive Neuro Fuzzy Inference System) tool in MATLAB software has been used to predict the surface roughness and results show good agreement between the measured value and predicted value.*

Keywords- *Turning Operation, Surface Roughness, ANFIS, Prediction, CNC*

I. INTRODUCTION

Surface finish is one of the most important quality characteristics in manufacturing industries which influences the performance of mechanical parts as well as production cost. In recent times, modern industries are trying to achieve the high quality products in a very short time with less operator input. For that purpose, the computer numerically controlled (CNC) machine tools with automated and flexible manufacturing systems have been implemented. In the manufacturing industries, various manufacturing processes are adopted to remove the material from the work piece. Out of these, turning is the first most common method for metal cutting because of its ability to remove materials faster with a reasonable good surface quality. In actual practice, there are many factors which affect surface roughness, e.g., cutting conditions, tool variables and workpiece variables. Cutting conditions include speed, feed and depth of cut whereas tool variables include tool material, nose radius, rake angle, cutting edge geometry, tool vibration, tool overhang, tool point angle etc. and workpiece variable include material hardness and other mechanical properties. However, it is very difficult to control all the parameters at a time that affect the surface roughness for a particular manufacturing process. In a turning operation, it is a vital task to select the cutting parameters properly to achieve the high quality performance.

Palanikumar et al. [1] found that feed rate has greater influence on surface roughness parameter (*Ra*), followed by cutting speed and % volume fraction of SiC in machining of Al/SiC particulate composites. Zhong et al. [2] predicted surface roughness heights *Ra* and *Rt*of turned surface using neural network.Sahin and Motorcu [3] developed mathematical model of surface roughness parameter *Ra* in turning of mild steel with coated carbide tools using RSM. They concluded that feed rate is the main influencing factor on the surface roughness. Noordin et al. [4] described the performance of coated carbide tools using response surface methodology when turning AISI 1040 mild steel. They found that feed rate is the most significant parameter influencing the surface roughness *Ra* and tangential force. Choudhury and El Baradie [5] had predicted surface roughness parameter *Ra* using RSM when turning high strength steel.Azouzi and Guillot [6] utilized a neural network to construct an on-line prediction model for surface roughness.Dilbag Singh and P. VenkateswaraRao [7] conducted experiments to determine the effects of cutting conditions and tool geometry on the surface roughness in the finish hard turning of the bearing steel (AISI 52100) using mixed ceramic inserts made up of aluminum oxide and titanium carbide with different nose radius and different effective rake angles as cutting tools. They found that the feed is the most dominant factor determining the surface finish followed by nose radius and cutting velocity. Jiao et al.[8] used fuzzy adaptive network to model surface roughness in turning operation. Bhattacharya et al. [9] investigated the influence of cutting parameters on the surface finish and power consumption using Taguchi design and analysis of variance. Several techniques including multiple regression, Taguchi, fuzzy logic, artificial neural network (ANN), and adaptive neuro-fuzzy inference system (ANFIS) have been used to predict surface roughness in various cutting processes [10–16].

II. EXPERIMENTS

2.1. EXPERIMENTAL SETUP

AISI 1040 steel was used as workpiece material in the experiments. The workpiece material used was in the form of round bar with 32 mm diameter. The chemical composition of workpiece material is shown in Table 1. This material is selected in this study because it is most widely used material in industry. The experiment was carried out on a Turn MasterGF 165-A CNC Machine tool shown in Fig. 2. The tool holder used was DCLNL 2020 M12 and the tool insert used is PVD Coated CNMG120408. The roughness tester used for measuring surface roughness of steel bar is Mitutoyo SJ210 roughness tester shown in fig. 3 and its measurement range is -200µm to 160µm.

Table 1.Chemical Composition

Element	Content (%)
Iron, Fe	98.6-99
Silicon, Si	0.159
Manganese, Mn	0.712
Carbon, C	0.411
Sulphur, S	0.028
Phosphorous, P	0.033

Figure 1 CNC Machine

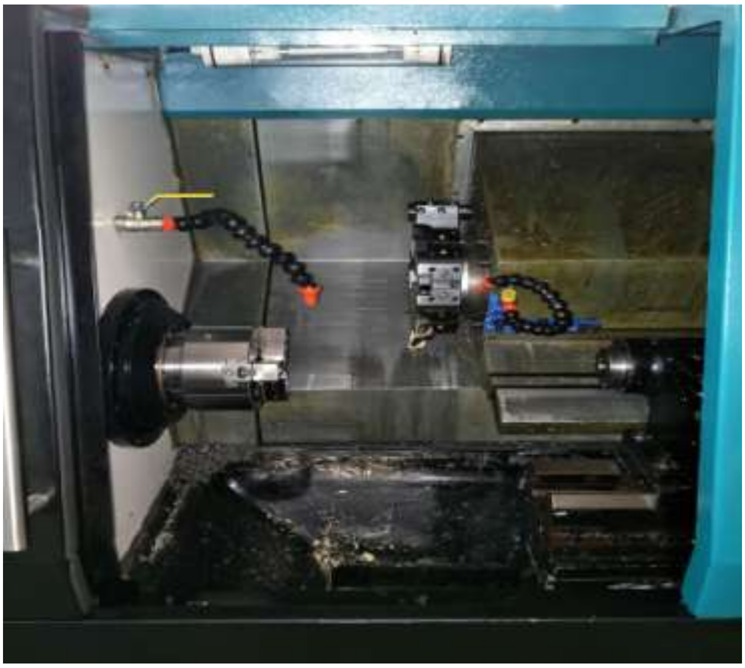

Figure 2 CNC Machine Tool

Figure 3 Surface Roughness Tester

2.2. EXPERIMENTATION

First of all trial experiments were conducted for finding out the effect of each parameter on surface roughness and for deciding the levels of different parameters for experiments. The following table 2 shows the trial experiments.

Table 2. Trial Experiments

Sr. No.	Cutting Speed (m/min)	Feed Rate (mm/rev)	Depth of Cut (mm)	Surface Roughness (µm)
1	50	0.1	0.4	3.744
2	100	0.1	0.4	3.608
3	150	0.1	0.4	3.118
4	200	0.1	0.4	0.791
5	240	0.1	0.4	0.591
6	200	0.05	0.5	0.334
7	200	0.08	0.5	0.662
8	200	0.12	0.5	0.868
9	200	0.16	0.5	1.069
10	200	0.2	0.5	1.283
11	200	0.1	0.2	1.071
12	200	0.1	0.8	0.872
13	200	0.1	1.1	0.554
14	200	0.1	1.5	0.526
15	200	0.1	2	0.557
16	200	0.1	2.5	0.585

Then according to the results obtained from trial experiments parameters and their levels were decided as shown in table 3 and the Experiments were performed according to L27 orthogonal array, which has 27 rows corresponding to the number of experiments with 3 columns at 3 levels.

Table 3.Parameters and their levels

Parameters	Unit	Level 1	Level 2	Level 3
Cutting Speed	m/min	80	160	240
Feed rate	mm/rev	0.05	0.1	0.15
Depth of Cut	mm	0.5	1.5	2.5

The experiments are performed according to L27 Orthogonal array and the surface roughness is measured using Mitutoyo SJ210 roughness tester and the average value is taken and the results are shown in table 4. The workpieces after performing turning operation on CNC machine are shown in Figure 4.

Table 4. Experimental results

Sr. No.	Cutting Speed (m/min)	Feed Rate (mm/rev)	Depth of Cut (mm)	Surface Roughness (µm)
1	80	0.05	0.5	2.196
2	80	0.05	1.5	2.668
3	80	0.05	2.5	1.69
4	80	0.1	0.5	3.376
5	80	0.1	1.5	2.075
6	80	0.1	2.5	1.332
7	80	0.15	0.5	2.685
8	80	0.15	1.5	1.805
9	80	0.15	2.5	1.358
10	160	0.05	0.5	0.665
11	160	0.05	1.5	0.476
12	160	0.05	2.5	0.418
13	160	0.1	0.5	0.778
14	160	0.1	1.5	0.787
15	160	0.1	2.5	0.63
16	160	0.15	0.5	0.974
17	160	0.15	1.5	0.984
18	160	0.15	2.5	1.271
19	240	0.05	0.5	0.385
20	240	0.05	1.5	0.608
21	240	0.05	2.5	0.679
22	240	0.1	0.5	0.643
23	240	0.1	1.5	0.693
24	240	0.1	2.5	0.703
25	240	0.15	0.5	0.874
26	240	0.15	1.5	0.939
27	240	0.15	2.5	0.845

Figure 4.Workpieces after turning

III.ANFIS PREDICTION MODEL

ANFIS (Adaptive Neuro Fuzzy Inference System) is a tool in MATLAB software which is used here to predict surface roughness. Here, the data is loaded in the ANFIS tool from workspace and then it is trained and the triangular membership function is selected. Then epochs are run and we get least RMSE (Root Mean Square Error) at 47 epochs which is 0.12696 which is shown in figure 5.

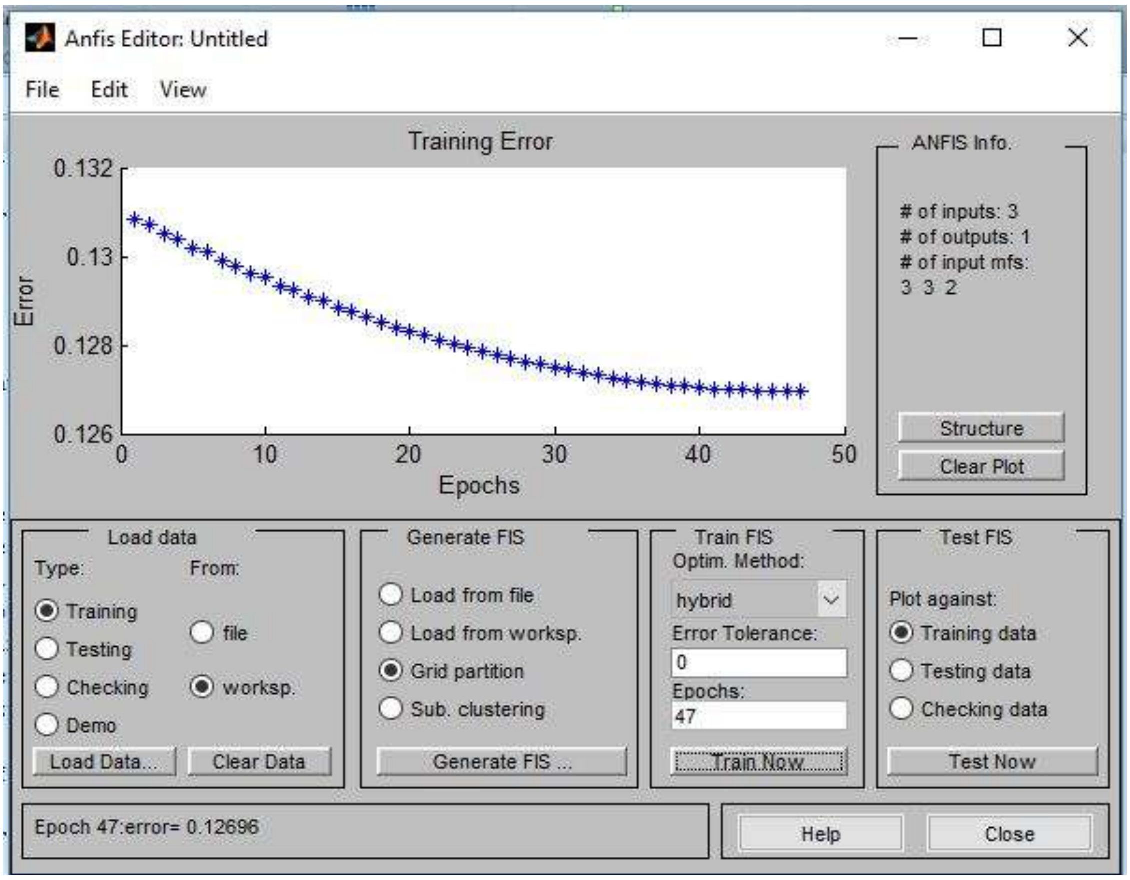

Figure 5. ANFIS Window showing least error at epoch 47

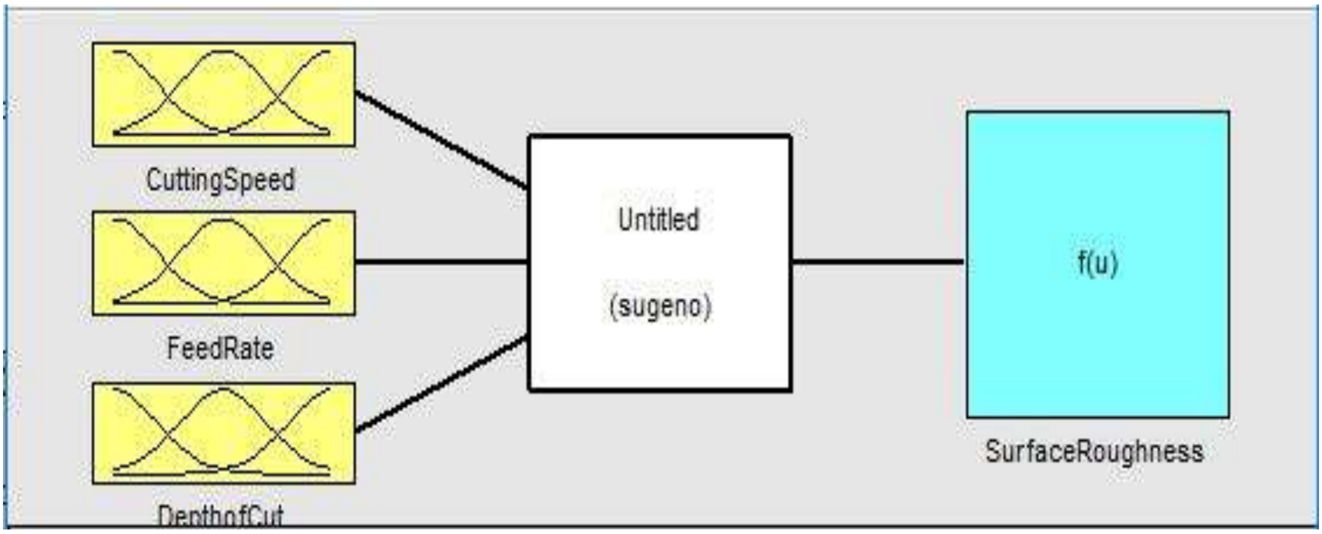

Figure 6. Input parameters and Output parameter

In figure 6 the input and output parameters are shown and figure 7 shows ANFIS Model Structure. Figure 8 shows the rule viewer which is used for prediction of surface roughness.

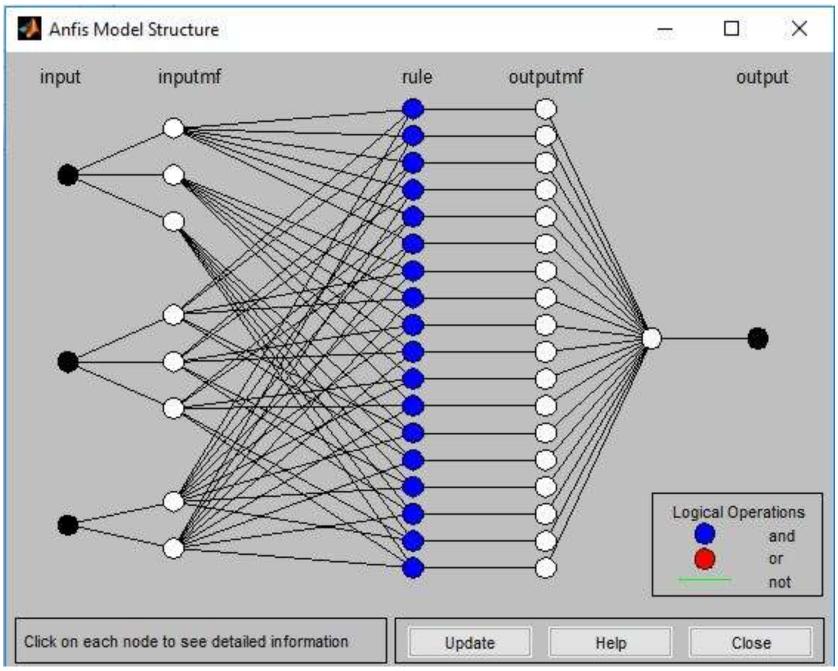

Figure 7. ANFIS Model Structure

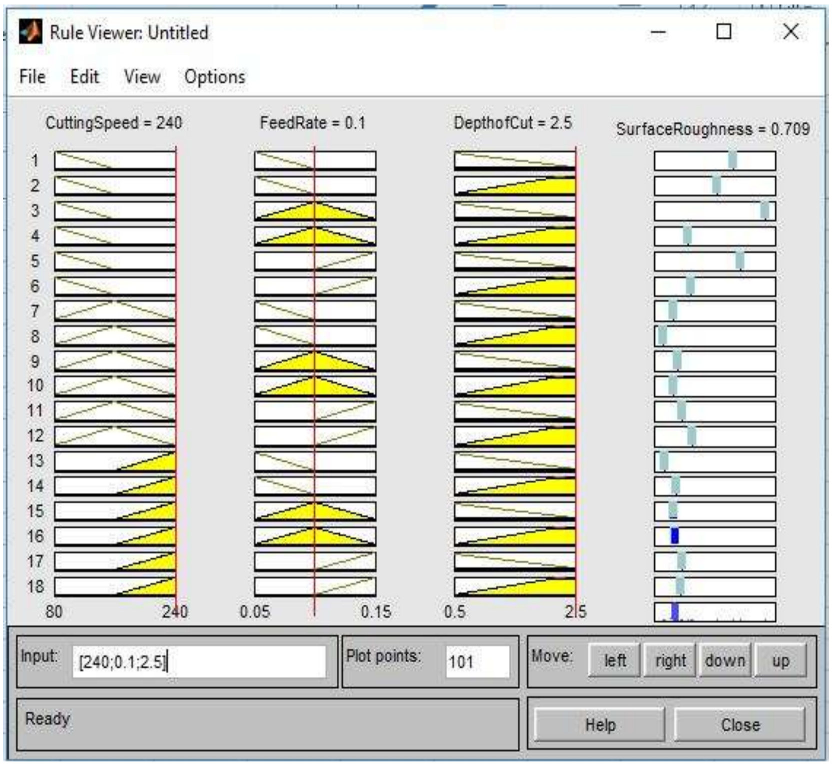

Figure 8. Rule Viewer for Surface Roughness Prediction

IV. RESULTS AND DISCUSSION

Using ANFIS model the surface roughness is predicted and the predicted surface roughness is shown in table 4. The interaction Surface plots of cutting speed, feed rate and surface roughness is shown in figure 9. Similarly interaction plots of cutting speed, depth of cut and surface roughness is shown in figure 10 and interaction plot of feed rate, depth of cut and surface roughness is shown in figure 11. Table 5 shows the values of predicted surface roughness and the results shows very close agreement with the actual measured surface roughness value. Figure 12 shows the actual surface roughness value v/s predicted surface roughness value plot which also shows good agreement between measured and predicted value. Figure 13 shows the line graph of actual and predicted value of surface roughness. Thus ANFIS model can be used in the prediction of surface roughness as it shows good prediction accuracy.

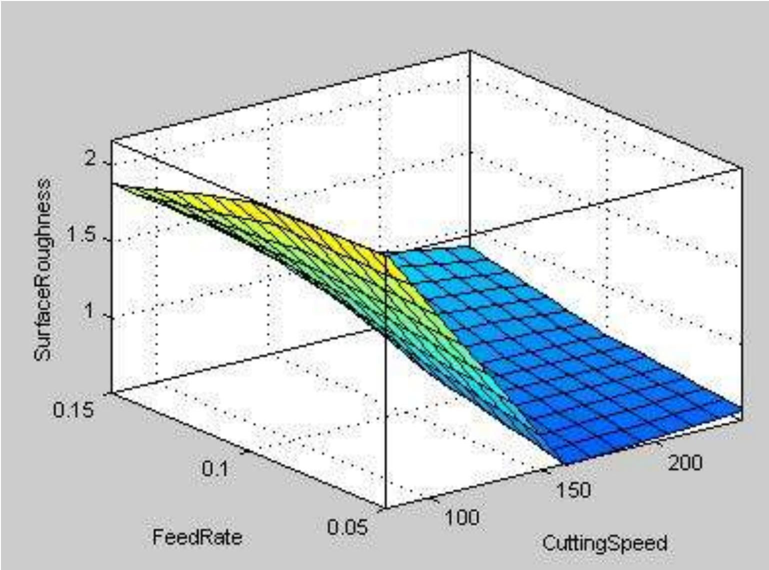

Figure 9. Interaction surface plot of cutting speed, feed rate and surface roughness

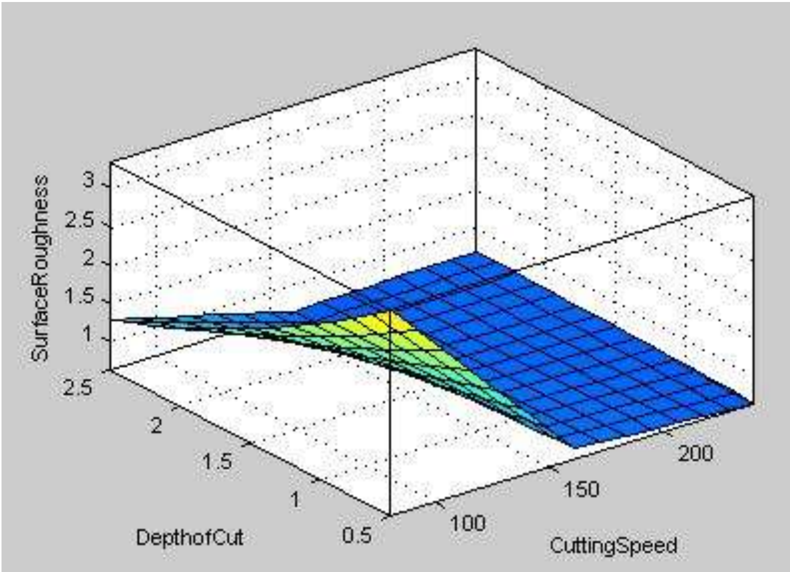

Figure 10. Interaction surface plot of cutting speed, depth of cut and surface roughness

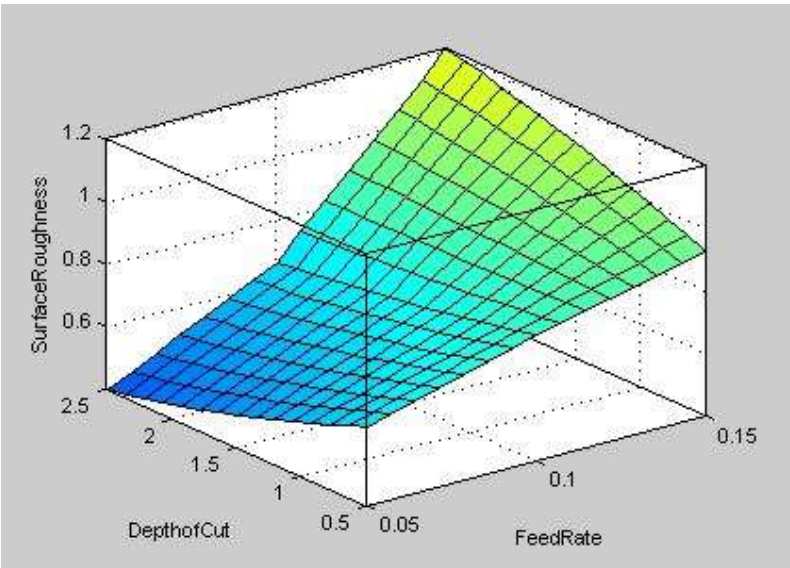

Figure 11. Interaction plot of feed rate, depth of cut and surface roughness

Table 5. Prediction of surface roughness using ANFIS

Sr. No.	Cutting Speed (m/min)	Feed Rate (mm/rev)	Depth of Cut (mm)	Surface Roughness (µm)	Predicted Surface Roughness using ANFIS (µm)
1	80	0.05	0.5	2.196	2.41
2	80	0.05	1.5	2.668	2.16
3	80	0.05	2.5	1.69	1.99
4	80	0.1	0.5	3.376	3.35
5	80	0.1	1.5	2.075	2.14
6	80	0.1	2.5	1.332	1.29
7	80	0.15	0.5	2.685	2.66
8	80	0.15	1.5	1.805	1.87
9	80	0.15	2.5	1.358	1.32
10	160	0.05	0.5	0.665	0.653
11	160	0.05	1.5	0.476	0.505
12	160	0.05	2.5	0.418	0.401
13	160	0.1	0.5	0.778	0.804
14	160	0.1	1.5	0.787	0.724
15	160	0.1	2.5	0.63	0.667
16	160	0.15	0.5	0.974	0.929
17	160	0.15	1.5	0.984	1.09
18	160	0.15	2.5	1.271	1.21
19	240	0.05	0.5	0.385	0.399
20	240	0.05	1.5	0.608	0.574
21	240	0.05	2.5	0.679	0.699
22	240	0.1	0.5	0.643	0.647
23	240	0.1	1.5	0.693	0.683
24	240	0.1	2.5	0.703	0.709
25	240	0.15	0.5	0.874	0.896
26	240	0.15	1.5	0.939	0.885
27	240	0.15	2.5	0.845	0.877

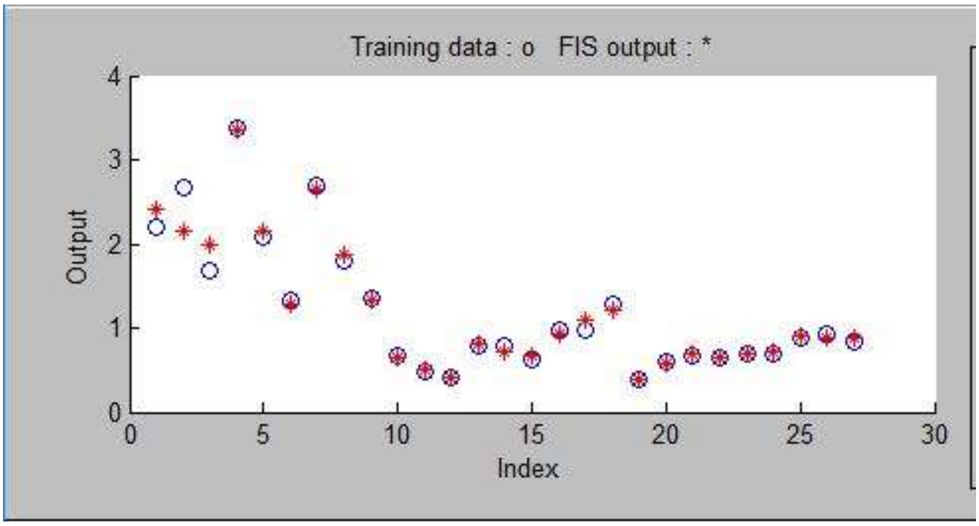

Figure 12. Actual Surface Roughness value v/s predicted surface roughness value plot

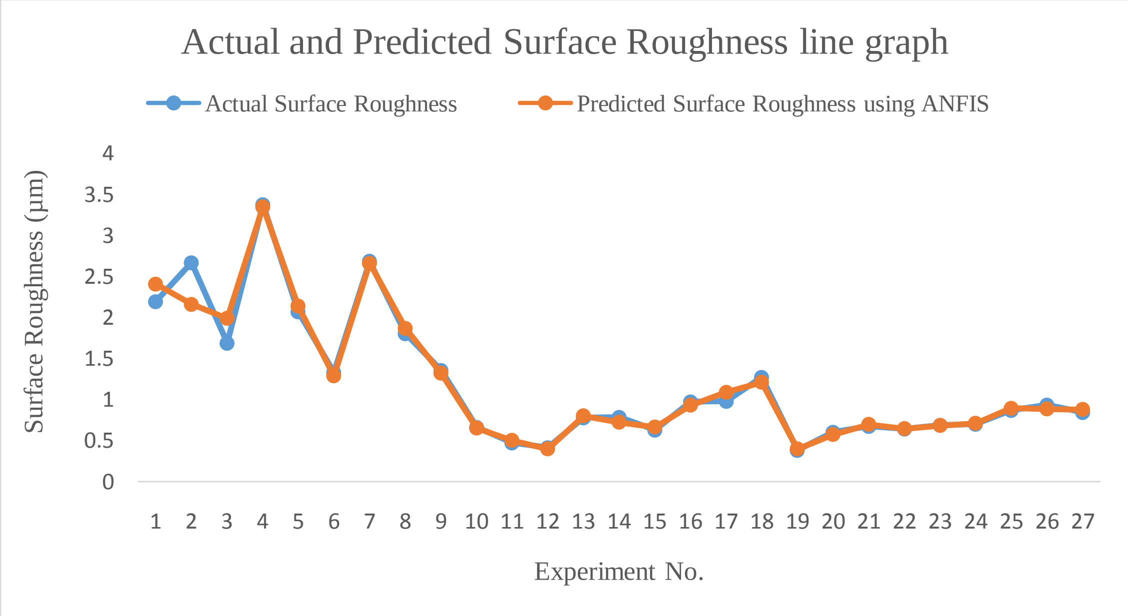

Figure 13. Actual and predicted surface roughness line graph

V. CONCLUSIONS

From the above experiments it is found that feed rate and cutting speed are the most influential parameters on surface roughness. As the cutting speed goes on increasing the surface roughness decreases. As the feed rate increases the surface roughness also increases and as depth of cut increases the surface roughness decreases initially and then it increases after a certain point. Turning at high cutting speed and lower feed rate gives better surface finish. At cutting speed 240 m/min, feed rate 0.05 mm/min and depth of cut 0.5 mm best surface finish is obtained i.e., 0.385 µm. ANFIS model gives satisfactory results and the predicted surface roughness value shows good agreement with actual surface roughness value. Thus ANFIS can be effectively used to predict surface roughness.

REFERENCES

[1] Palanikumar, K; Karthikeyan, R. (2007). Optimal machining conditions for turning of particulate metal matrix composites using Taguchi and response surface methodologies, Machining Science and Technology, An Int.Journal,10, 417–433

[2] Zhong, Z. W.; Khoo, L. P.; Han, S. T. (2006). Prediction of surface roughness of turned surfaces using neural networks, Int. J. Adv. Manuf. Technol., 28, 688–693

[3] Sahin, Y.; RizaMotorcu, A. (2005). Surface roughness model for machining mild steel with coated carbide tool, Materials and Design, 26, 321–326

[4] Noordin, M.Y.; Venkatesh, V. C.; Sharif, S.; Elting, S.; Abdullah, A. (2004). Application of response surface methodology in describing the performance of coated carbide tools when turning AISI 1045 steel, Journal of Materials Processing Technology, 145, 46–58

[5] Choudhury, I. A.; El-Baradie, M. A. (1997). Surface roughness prediction in the turning of high-strength steel by factorial design of experiments, Journal of Materials Processing Technology, 67(1-3), 55-61

[6] R. Azouzi, M. Guillot, On-line prediction of surface finish and dimensional deviation in turning using neural network based sensor fusion, Int. J. Mach. Tools Manuf. 37 (9) (1997) 1201±1217.

[7] D. Singh, P. VenkateswaraRao, "A surface roughness prediction model for hard turning process". International Journal of Advanced Manufacturing, Vol. 32, No.11-12, 2007, 1115-1124.

[8]Jiao, Y., Lei, S., Pei, Z.J., Lee, E.S. (2004), "Fuzzy Adaptive Networks in process modeling: surface roughness prediction for turning operations", International Journal of Machine Tools and Manufacture, 44(15), 1643–1651.

[10] Asiltürk İ, Çunkaş M (2011) Modeling and prediction of surface roughness in turning operations using artificial neural network and multiple regression method. Expert SystAppl 38(5):5826–5832.

[11] Asiltürk İ (2012) Predicting surface roughness of hardened AISI 1040 based on cutting parameters using neural networks and multiple regression. Int J AdvManufTechnol 63(1–4):249–257.

[12] Sayuti M, Sarhan AAD, Fadzil M, Hamdi M (2012) Enhancement and verification of a machined surface quality for glass milling operation using CBN grinding tool—Taguchi approach. Int J AdvManufTechnol 60(9–12):939–950.

[13] Bagci E, Aykut Ş (2005) A study of Taguchi optimization method for identifying optimum surface roughness in CNC face milling of cobalt-based alloy (stellite 6). Int J AdvManufTechnol 29(9–10): 940–947.
[14] Zalnezhad E, Sarhan AAD, Hamdi M (2013) A fuzzy logic based model to predict surface hardness of thin film TiN coating on aerospace AL7075-T6 alloy. Int J AdvManufTechnol 68(1–4):415–423.
[15] Kohli A, Dixit US (2004) A neural-network-based methodology for the prediction of surface roughness in a turning process. Int J AdvManufTechnol 25(1–2):118–129.
[16] Abdel Badie S (2011) Prediction of surface roughness in end milling process using intelligent systems: a comparative study. ApplComput Intel Soft Comput.
[17] Kiran A Patel, Pragnesh K Brahmbhatt, A comparative study of the RSM and ANN models for predicting surface roughness in roller burnishing, Procedia Technology 23 (2016):391 – 397.
[18] Kiran A Patel, Pragnesh K Brahmbhatt, Comparative Analysis for Surface Roughness of Al Alloy 6061 using MLR and RSM, International Journal of Computer Applications (0975 – 8887) Volume 117 – No. 9, May 2015.

