



INSTITUTE OF ENGINEERING
AND TECHNOLOGY

JK LakshmiPat University Jaipur
INSTITUTE OF ENGINEERING AND TECHNOLOGY

B. Tech. Mechanical Engineering

4th Year (7th Semester)

Term-III Examination, Dec, 2022

Course No. : ME1209
Course Title : Modelling of Engineering Materials
Nature of Exam : Closed Book
Max Marks : 40
Duration : 3 Hrs.

No. of Pages = 01

No. of Questions = 06

Roll No: _____

Note:

1. Draw neat diagrams using pencil (if required).
2. All questions are compulsory.
3. Assume data as and when required
4. Write only Roll No in Question Paper

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- 1 Compare the properties of metals, ceramics and polymers as matrix materials. Explain briefly any two methods used for producing laminar composites. Give examples and industrial applications for laminar composites. MM:5 CO1
 - 2 Discuss the (a) fatigue and (b) impact behavior of composites with suitable example. Write stiffness matrix for plane stress. MM:5 CO3
 - 3 What are honeycomb structures? What are the functions of core and facing material in a honeycomb? Give examples and industrial applications of honeycomb structure composite. MM:5 CO2
 - 4 Discuss the production of glass fibers in detail using a neat sketch. Give the composition of E glass and S glass. MM:5 CO3
 - 5 Why classification of modelling of materials response becomes important for researchers. Using suitable example explain about empirical models and its application in real product development. MM:10 CO4
 - 6 Discuss about the process followed to obtain the optimized output also write about the ANFIS tool and the steps involved to develop the mathematical model for given case. Refer to the annexure-1. MM:10 CO4

Annex. 01

ANFIS tool and found that the predicted results are very close to the experimental data [14]. The effect of different turning parameters speed, feed, and depth of cut on material removal rate and surface roughness of stainless steel 202 was studied and found that ANFIS model predicts the value of output parameters with an accuracy more than 98 percent [15].

In this paper a method has been developed to model a process using ANFIS to determine the surface roughness value for three different materials (Aluminum, Copper, Brass). The Poisson's ratio are 0.334, 0.355, 0.357 for Aluminum, Copper, and Brass respectively [16]. The change in the Poisson's ratio was to observe the response of machining parametric values and to estimate the variation in surface roughness value. For modelling the machining process experiments were conducted as per full factorial and Taguchi method. L9 orthogonal array has been used to design the experiments for Taguchi method the details are discussed in the following sections.

II. Experimental Procedure

For investigating the effect of Poisson's ratio on surface roughness, we have considered three different materials (Aluminum, Copper, Brass). Some of the machining process parameters are important and it significantly influences the surface roughness [1, 8]. The process parameters (input) which were selected for investigation are spindle speed, depth of cut and feed rate. We have considered three different levels

for each input parameter for conducting the experiment as tabulated in Table 1 [4, 7, 8, 10]. Selected specimen was having diameter 12mm and length 70mm in order to suffice the machining and surface roughness requirement.

Table 1: Input Process Parameter with levels

Symbol	Parameters	Unit	Levels		
			1	2	3
X ₁	Spindle Speed	Rpm	1500	2000	2500
X ₂	Feed Rate	mm/min	70	80	90
X ₃	Depth of Cut	Mm	0.25	0.5	0.75

The experiments were performed for two different series. In first series we have used Taguchi method, where L9 orthogonal array were used for conducting the experiment. In this method we have conducted nine experiments in three repetition for each material resulted in to eighty one (9X3X3) experiments. In the second series of experiments full factorial was used, where 27 experiments in three repetition for each material resulted into 243(3³ X 3 X 3) experiments. Thus, total number of experiments (turning) were finalized. The experiments (i.e., turning operation using CNC turning machine-MTAB) were performed and surface roughness (R_a) value were measured using surface roughness testing machine (Digital Surface Roughness Tester of Model: SJ-210) as shown in Figure 1. Based on these values the signal to noise ratio (SNR) were determined. The SNR is a function of mean of sum of square of average roughness value (R_a), where $SNR = -10 \log_{10} \left(\frac{1}{n} \sum_{i=1}^n R_a^2 \right)$.

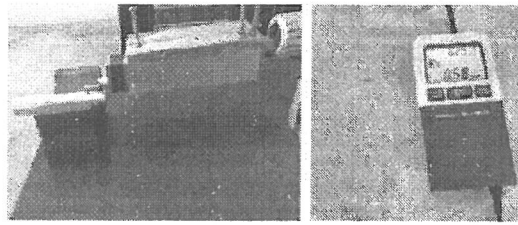


Fig.1: Surface Roughness Testing Machine (Model: SJ-210)

Table 2 (a), (b), and (c) are the experimental results for Taguchi Method and Table 3 (a), (b), and (c) are for full factorial, where for input parameters (spindle speed, feed rate, and depth of cut), the output parameter (surface roughness) was determined for three trails. Mean for these trial were determined and the SNR were calculated.

Table 2(a) Taguchi data with trail variation (Aluminum)

S No	Spindle Speed (rpm)	Feed Rate (mm/min)	Depth of Cut (mm)	Mean (R_a)	Ra (Trail 1)	Ra (Trail 2)	Ra (Trail 3)	SNR
1	1500	70	0.25	0.40	0.39	0.40	0.41	7.96
2	1500	80	0.5	0.70	0.70	0.69	0.72	3.06
3	1500	90	0.75	0.59	0.58	0.59	0.59	4.63
4	2000	70	0.5	2.35	2.41	2.20	2.44	-7.43
5	2000	80	0.75	0.55	0.57	0.53	0.56	5.14
6	2000	90	0.25	0.40	0.40	0.42	0.38	7.95
7	2500	70	0.75	2.25	2.26	2.24	2.25	-7.04
8	2500	80	0.25	1.26	1.25	1.26	1.28	-2.03
9	2500	90	0.5	1.44	1.44	1.42	1.46	-3.17

Table 2(b) Taguchi data with trail variation (Copper)

S No	Spindle Speed (rpm)	Feed Rate (mm/min)	Depth of Cut (mm)	Mean (R_a)	Ra (Trail 1)	Ra (Trail 2)	Ra (Trail 3)	SNR
1	1500	70	0.25	0.85	0.90	0.78	0.88	1.36
2	1500	80	0.5	0.82	0.82	0.78	0.86	1.72

3	1500	90	0.75	2.99	3.46	2.70	2.80	-9.56
4	2000	70	0.5	0.75	0.59	0.68	0.98	2.29
5	2000	80	0.75	1.83	1.70	1.89	1.90	-5.26
6	2000	90	0.25	1.06	1.00	1.09	1.09	-0.51
7	2500	70	0.75	0.92	1.20	0.85	0.72	0.49
8	2500	80	0.25	1.40	1.40	1.39	1.41	-2.92
9	2500	90	0.5	1.93	1.90	2.10	1.80	-5.74

Table 2(c) Taguchi data with trail variation (Brass)

S No	Spindle Speed (rpm)	Feed Rate (mm/min)	Depth of Cut (mm)	Mean (R_a)	Ra (Trail 1)	Ra (Trail 2)	Ra (Trail 3)	SNR
1	1500	70	0.25	1.63	1.65	1.69	1.54	-4.23
2	1500	80	0.5	1.67	1.60	1.75	1.67	-4.48
3	1500	90	0.75	2.24	2.20	2.55	1.98	-7.07
4	2000	70	0.5	1.57	1.40	1.73	1.58	-3.95
5	2000	80	0.75	1.19	1.00	1.30	1.10	-1.14
6	2000	90	0.25	1.51	1.47	1.48	1.59	-3.60
7	2500	70	0.75	2.39	2.70	2.38	2.60	-8.18
8	2500	80	0.25	2.11	2.00	2.10	2.23	-6.49
9	2500	90	0.5	2.93	2.80	3.10	2.90	-9.36

Table 3(a): Full factorial data with three trails for Aluminum

S No	Spindle Speed (rpm)	Feed Rate	Depth of Cut (mm)	Mean (R_a)	Ra (Trail 1)	Ra (Trail 2)	Ra (Trail 3)	SNR
1	2000	80	0.5	0.76	0.73	0.74	0.8	2.41
2	2000	80	0.25	0.46	0.46	0.44	0.48	6.74

3	2000	80	0.75	0.55	0.57	0.53	0.56	5.14
4	2000	70	0.5	2.35	2.41	2.2	2.44	-7.43
5	2000	70	0.25	0.41	0.41	0.4	0.43	7.67
6	2000	70	0.75	0.62	0.63	0.6	0.64	4.1
7	2000	90	0.5	0.41	0.41	0.4	0.42	7.74
8	2000	90	0.25	0.4	0.4	0.42	0.38	7.95
9	2000	90	0.75	0.52	0.54	0.52	0.49	5.73
10	1500	80	0.5	0.7	0.7	0.69	0.72	3.06
11	1500	80	0.25	0.54	0.53	0.55	0.54	5.35
12	1500	80	0.75	0.45	0.46	0.45	0.44	6.93
13	1500	70	0.5	0.73	0.74	0.73	0.72	2.73
14	1500	70	0.25	0.4	0.39	0.4	0.41	7.96
15	1500	70	0.75	0.38	0.37	0.38	0.39	8.4
16	1500	90	0.5	0.51	0.5	0.51	0.52	5.85
17	1500	90	0.25	0.46	0.45	0.46	0.46	6.81
18	1500	90	0.75	0.59	0.58	0.59	0.59	4.63
19	2500	80	0.5	1.55	1.58	1.56	1.5	-3.79
20	2500	80	0.25	1.26	1.25	1.26	1.28	-2.03
21	2500	80	0.75	1.75	1.77	1.79	1.7	-4.88
22	2500	70	0.5	1.82	1.85	1.79	1.82	-5.2
23	2500	70	0.25	0.94	0.94	0.92	0.96	0.54
24	2500	70	0.75	2.25	2.26	2.24	2.25	-7.04
25	2500	90	0.5	1.44	1.44	1.42	1.46	-3.17
26	2500	90	0.25	1.69	1.69	1.68	1.7	-4.56
27	2500	90	0.75	0.43	0.42	0.43	0.44	7.33

Table 3(b): Full factorial data with three trails for Copper

S No	Spindle Speed (rpm)	Feed Rate	Depth of Cut (mm)	Mean (R_a)	Ra (Trail 1)	Ra (Trail 2)	Ra (Trail 3)	SNR
1	2000	80	0.5	1.79	1.78	1.8	1.79	-5.06
2	2000	80	0.25	1.82	1.8	1.84	1.82	-5.2
3	2000	80	0.75	1.83	1.7	1.89	1.9	-5.26
4	2000	70	0.5	0.75	0.59	0.68	0.98	2.29
5	2000	70	0.25	1.21	1.21	1.19	1.23	-1.66
6	2000	70	0.75	0.75	0.95	0.6	0.69	2.37
7	2000	90	0.5	1.26	1	1.46	1.32	-2.11
8	2000	90	0.25	1.06	1	1.09	1.09	-0.51
9	2000	90	0.75	1.39	1.38	1.38	1.41	-2.86
10	1500	80	0.5	0.82	0.82	0.78	0.86	1.72
11	1500	80	0.25	2.11	2.14	2.12	2.13	-6.57
12	1500	80	0.75	0.85	0.9	0.7	0.95	1.34
13	1500	70	0.5	2.01	1.7	2.4	1.93	-6.15
14	1500	70	0.25	0.85	0.9	0.78	0.88	1.36
15	1500	70	0.75	0.83	0.82	0.82	0.85	1.62
16	1500	90	0.5	2.67	2.67	2.67	2.66	-8.52
17	1500	90	0.25	1.04	1	1.04	1.09	-0.37
18	1500	90	0.75	2.99	3.46	2.7	2.8	-9.56
19	2500	80	0.5	5.07	5	5	5.2	-14.1
20	2500	80	0.25	1.4	1.4	1.39	1.41	-2.92
21	2500	80	0.75	0.61	0.6	0.62	0.61	4.29
22	2500	70	0.5	1.39	1.41	1.38	1.39	-2.88
23	2500	70	0.25	3.25	3	3.05	3.7	-10.28
24	2500	70	0.75	0.92	1.2	0.85	0.72	0.49
25	2500	90	0.5	1.93	1.9	2.1	1.8	-5.74
26	2500	90	0.25	12.29	12.29	12.27	12.28	-21.78
27	2500	90	0.75	0.68	0.65	0.69	0.7	3.35

Table 3(c): Full factorial data with three trails for Brass

S No	Spindle Speed (rpm)	Feed Rate	Depth of Cut (mm)	Mean (R_a)	Ra (Trail 1)	Ra (Trail 2)	Ra (Trail 3)	SNR
1	2000	80	0.5	1.46	1.45	1.47	1.46	-3.29
2	2000	80	0.25	1.36	1.3	1.32	1.46	-2.68
3	2000	80	0.75	1.19	1	1.3	1.1	-1.14
4	2000	70	0.5	1.57	1.4	1.73	1.58	-3.95
5	2000	70	0.25	1.42	1.42	1.4	1.44	-3.05
6	2000	70	0.75	1.53	1.42	1.4	1.44	-3.05
7	2000	90	0.5	1.54	1.55	1.48	1.6	-3.77
8	2000	90	0.25	1.51	1.47	1.48	1.59	-3.6
9	2000	90	0.75	1.49	1.5	1.49	1.48	-3.46
10	1500	80	0.5	1.67	1.6	1.75	1.67	-4.48
11	1500	80	0.25	1.62	1.53	1.68	1.65	-4.2
12	1500	80	0.75	1.69	1.69	1.57	1.6	-4.19
13	1500	70	0.5	1.66	1.6	1.75	1.64	-4.43
14	1500	70	0.25	1.63	1.65	1.69	1.54	-4.23
15	1500	70	0.75	1.58	1.57	1.59	1.58	-3.97
16	1500	90	0.5	1.8	1.8	1.81	1.82	-5.15
17	1500	90	0.25	1.97	1.85	2.1	1.95	-5.89
18	1500	90	0.75	2.24	2.2	2.55	1.98	-7.07
19	2500	80	0.5	1.87	1.9	1.8	1.9	-5.42
20	2500	80	0.25	2.11	2	2.1	2.23	-6.49
21	2500	80	0.75	2.26	2.24	2.28	2.26	-7.08
22	2500	70	0.5	2.16	2.16	2.16	2.16	-6.69
23	2500	70	0.25	2.56	2.7	2.38	2.6	-8.18
24	2500	70	0.75	2.39	2.7	2.38	2.6	-8.18
25	2500	90	0.5	2.93	2.8	3.1	2.9	-9.36
26	2500	90	0.25	2.45	2.45	2.45	2.45	-7.78

27	2500	90	0.75	2.52	2.6	2.5	2.45	-8.02
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Table 4 (a): Response Table for Signal to Noise Ratios (*smaller is better*) for Aluminum

Level	A	B	C
1	5.21	-2.17	4.63
2	1.89	2.05	-2.51
3	-4.08	3.14	0.91
Delta	9.30	5.31	7.14
Rank	1	3	2

Table 4 (b): Response Table for Signal to Noise Ratios (*smaller is better*) for Copper

Level	A	B	C
1	-2.16	1.38	-0.69
2	-1.16	-2.16	-0.58
3	-2.73	-5.27	-4.78
Delta	1.56	6.65	4.20
Rank	3	1	2

Table 4 (c): Response Table for Signal to Noise Ratios (*smaller is better*) for Brass

Level	A	B	C
1	-5.26	-5.45	-4.78
2	-2.90	-4.04	-5.93
3	-8.01	-6.68	-5.46
Delta	5.11	2.64	1.15
Rank	1	2	3

The optimized value of process parameters to get minimum surface roughness values for materials with different Poisson's ratio are tabulated in Table 3 and Table 4. The optimum parameter levels obtained using Taguchi method were very close to the experimental values and is evident in Table 2 and therefore the Taguchi parameter design gives accurate results with lesser number of experiments.

Optimized surface roughness value for materials with different Poisson's ratio were further plotted as shown in the Figure 8 for useful analysis.

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Optimized surface roughness value for materials with different Poisson's ratio were further plotted as shown in the Figure 2 for useful analysis.

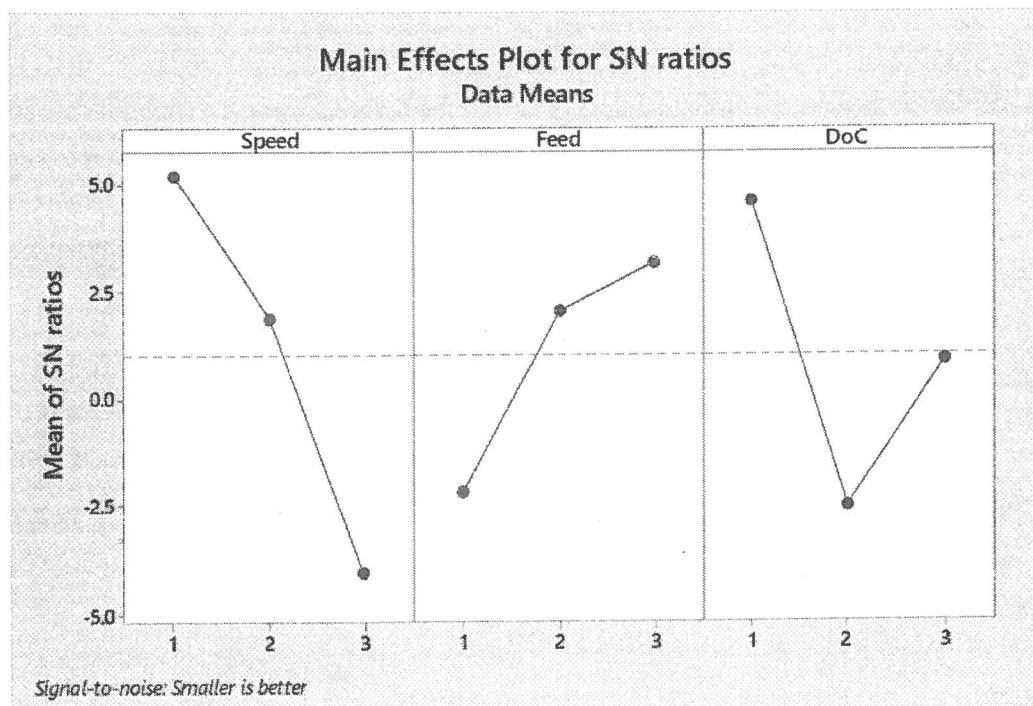


Fig. 2a. Plots for Mean of SN Ratios (Aluminum)

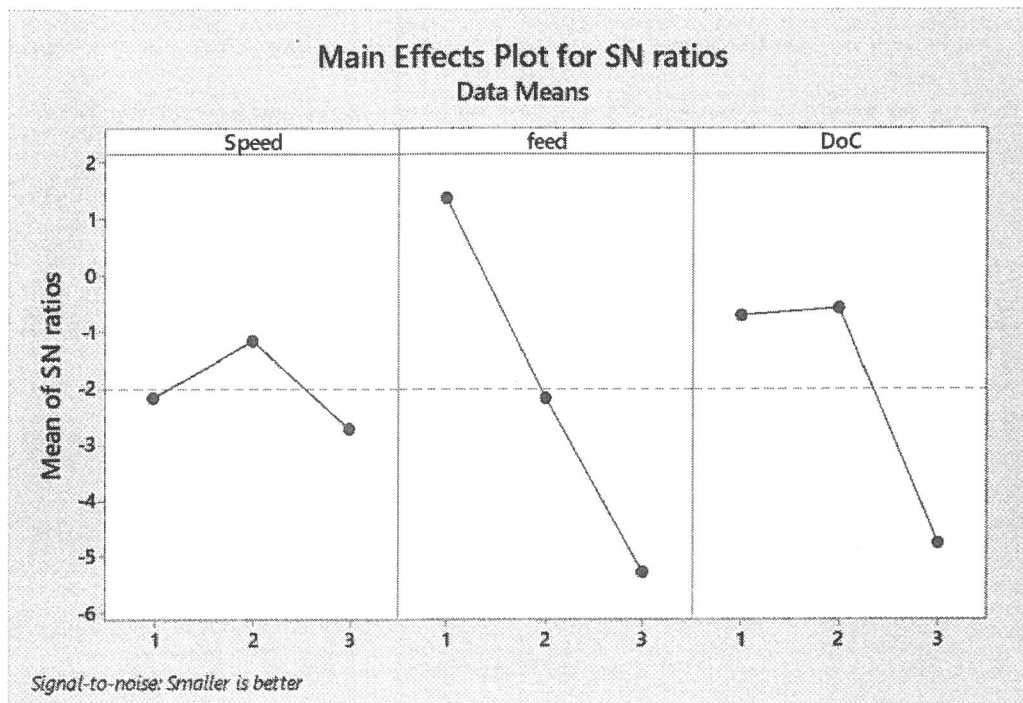


Fig. 2b. Plots for Mean of SN Ratios (Copper)

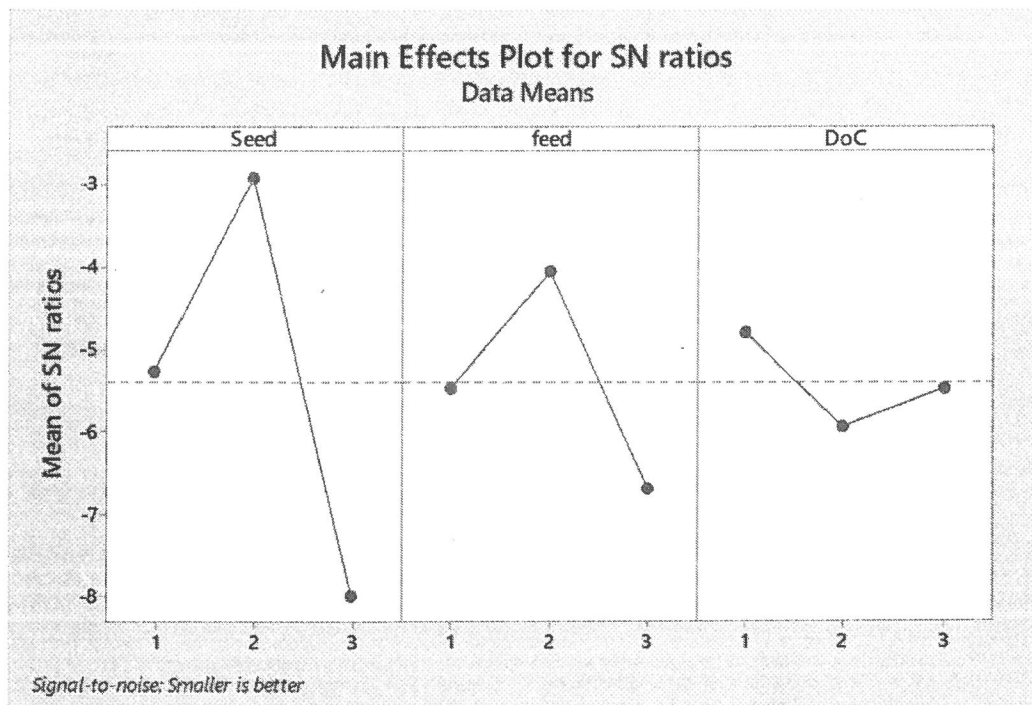


Fig. 2c. Plots for Mean of SN Ratios (Brass)

III. Adaptive Neuro-Fuzzy Interference System

Adaptive Neuro-Fuzzy Interference System (ANFIS) was used to model the machining parameters to predict surface roughness. The experimental data as obtained from the full-factorial method is used as an input file for developing Fuzzy Interference System (FIS). In this FIS system we have incorporated hybrid optimization method where 50 epochs within a tolerance of 0.00001 was used to generate FIS. The input membership function type was trapezoidal and output membership function type was linear. The FIS output is utilized to develop ANFIS model, which is further tested and verified with the experimental data (full-factorial random sample). The ANFIS model and

model structure generated is as shown in the figure 3 and figure 4 respectively is for Aluminum. The surface plot was generated based on the output from the ANFIS to observe the characteristics with variation in the input parametric values. For Aluminum number of fuzzy rules were 27 and the training completed at epoch 2 with training error of 0.00031373. Once training is over testing was performed. The thirty percent of the experimental data was used for the purpose. It was found that average testing error was 0.00014932. The plot of surface roughness against feed rate and spindle speed for aluminum is as shown in the figure 5a. The plot of surface roughness against depth of cut and spindle speed for aluminum is as shown in the figure 5b. Modelling process was further prepared for copper and brass.

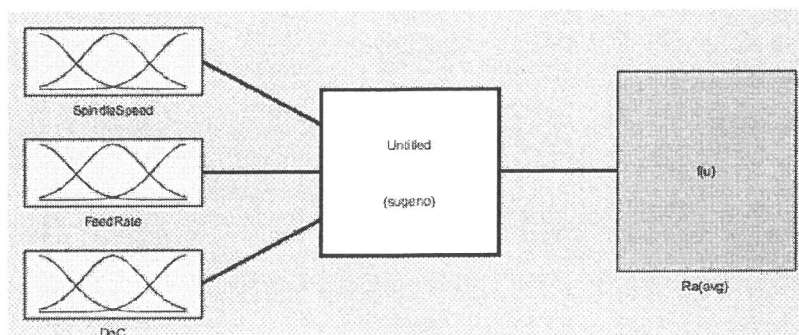


Fig. 3. ANFIS Model

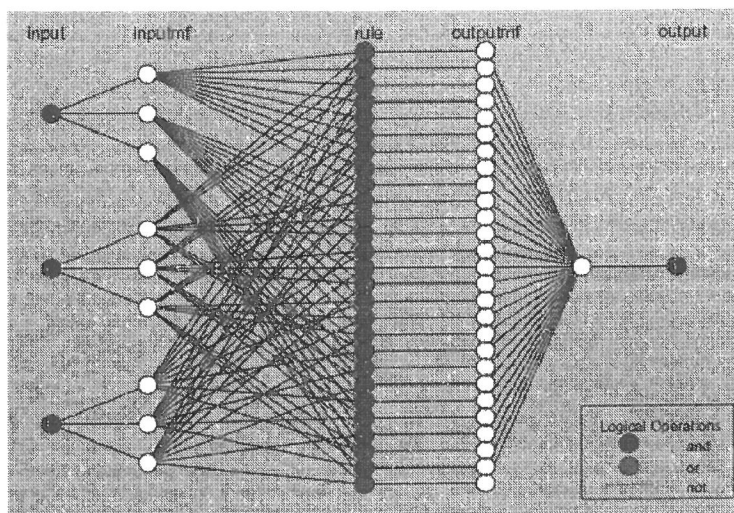


Fig. 4. Structure of ANFIS Model

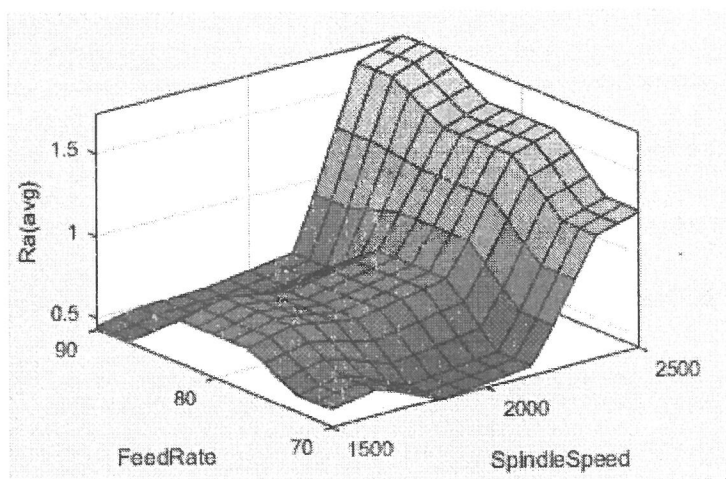


Fig. 5a. Plot of surface roughness with change in feed rate and spindle speed for aluminum

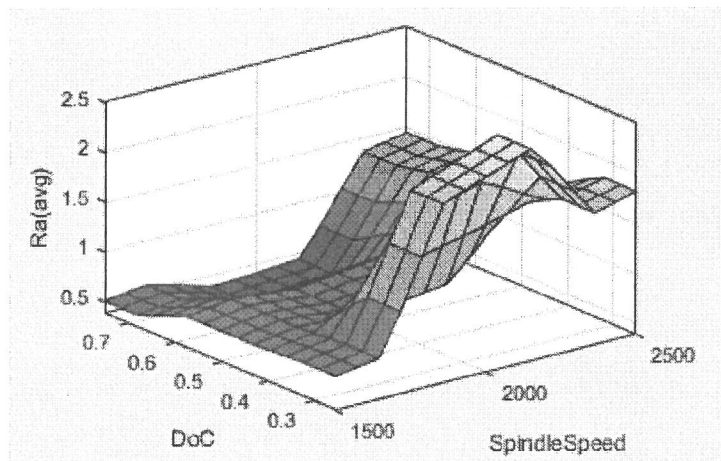


Fig. 5b. Plot of surface roughness with change in depth of cut (DoC) and spindle speed for aluminum

For copper the training completed at epoch 2 with training error of 0.00069659 and average testing error is 0.00025251. The plot of surface roughness against feed rate and spindle speed for copper is as shown in the figure 6a. The plot of surface roughness against depth of cut and spindle speed for copper is as shown in the figure 6b.

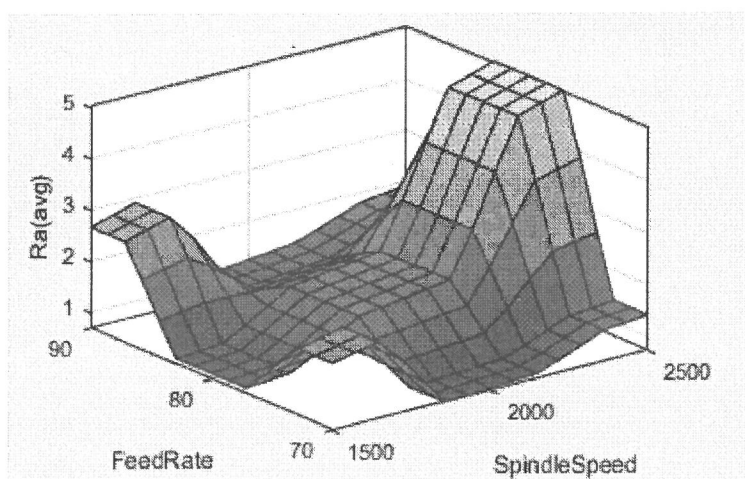


Fig. 6a. Plot of surface roughness with change in feed rate and spindle speed for copper

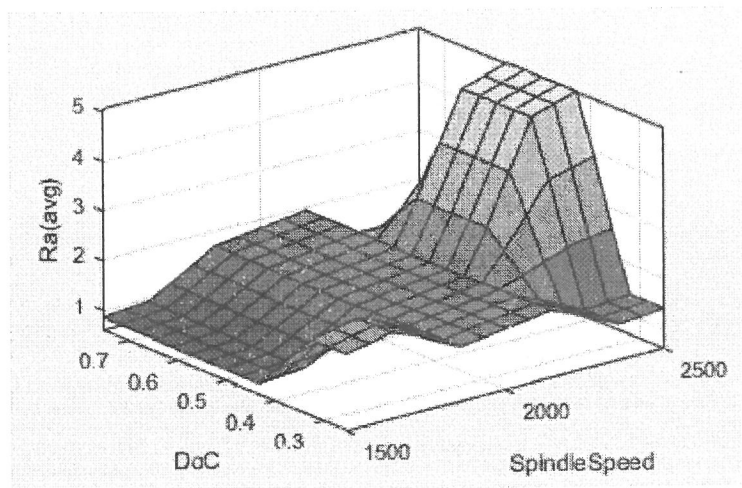


Fig. 6b. Plot of surface roughness with change in depth of cut (DoC) and spindle speed for copper

In case of brass the training completed at epoch 2 with training error of 0.0006061 and average testing error was 0.00052634. The plot of surface roughness against feed rate and spindle speed for brass is as shown in the figure 7a. The plot of surface roughness against depth of cut and spindle speed for brass is as shown in the figure 7b.

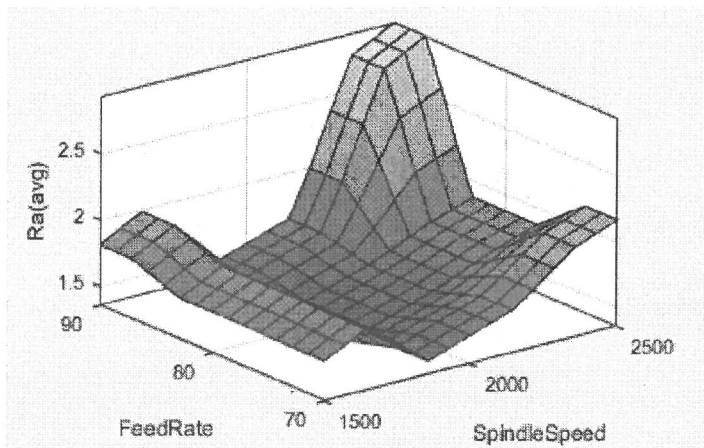


Fig. 7a. Plot of surface roughness with change in feed rate and spindle speed for brass

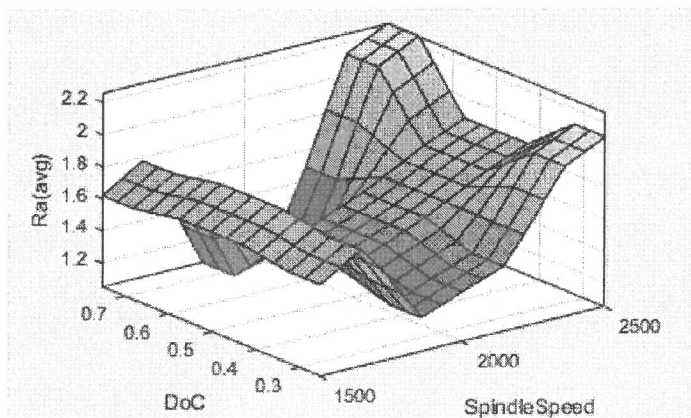


Fig. 7b. Plot of surface roughness with change in depth of cut (DoC) and spindle speed for brass

IV. Result and Discussion

A series of experiments were conducted for full factorial data set to determine the