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ANFIS based Model for Surface Roughness Prediction for Hard Turning with Minimal Cutting Fluid Application

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Abstract

Background/Objectives: Nowadays artificial intelligence plays an important role in manufacturing sector. How to utilize that in an effective manner is a key factor of optimization. So identification of optimal modeling tool for effective manufacturing gives an extraordinary output. **Methods/Statistical Analysis:** This paper develops an Adaptive Neuro Fuzzy Inference System (ANFIS) model with hybrid model to predict the Surface Roughness (SR) of the H13 tool steel work piece of 45 HRC hardness value. The investigation of operation has been done in hard turning using minimal cutting fluid application. **Findings:** The effect of the different input parameters like cutting force, temperature and vibration has been analyzed. Here the hybrid type of ANFIS model is created with triangular membership function and the observed results indicated that the predicted output surface roughness is almost very close to the actual output obtained in the experimental work.

Keywords: Artificial Intelligence, Fuzzy Inference System, Surface Roughness, Turning

1. Introduction

Modern manufacturing sectors are focusing on developing good quality components within a short period of time. Fully automated and semi-automated systems with flexible manufacturing concepts are introduced for that purpose only. Turing operation plays a vital role in cutting and finishing operations. During turning operation heat generation at high temperature is achieved due to friction developed between the tool and the work piece. To avoid that kind of situations cutting fluids are used as a coolant and lubricating agent. But it is high cost and makes pollution of waters due to improper disposals. Also this may cause health problems for the workers those whose who are largely working in it. In order to eliminate these kinds of problems there is a need of introducing alternate solution for that otherwise use that particular cutting fluid at minimal or optimized level.

2. Past Studies

In[1] investigated the turning of AISI1045 work pieces with minimum quantity lubrication using design of experiment for predicting the cutting force and surface roughness. The effects of the input parameters like cutting speed, feed rate, depth of cut, supplied air pressure and nozzle diameter are modeled by regression equation.

In[2] proposed an optimized model for dry hard turning using response surface methodology and the significance of the cutting parameters has been determined with the help of analysis of variance. The turning parameters considered here is cutting speed, feed and depth of cut. The optimized results showed that good surface finish has been achieved by low feed and depth of cut.

In[3] predicted the surface finish of the AISI D3 and AISI H13 hardened steel with 62 HRC using response surface methodology developed model has been checked

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by analysis of variance. Experimental design was created by central composite design for three parameters cutting speed, feed and depth of cut. Results finalized the most influential parameter as cutting speed. In[4] developed an artificial neural network model for predicted the surface roughness of the AISI 4340 steel in surface milling with minimal fluid application. Pressure at the fluid injector, frequency of pulsing and the rate of fluid application are considered as the varying parameters. The predicted output is almost very close to actual value. In[5] optimized the surface milling using minimal pulsed jet cutting fluid. The composition of 20% oil with water gave improved cutting performance compared with 10% oil with water. In[6] made an experimental investigation in CNC lathe turning for 316L stainless steel pipe using multiple regression analysis and artificial neural network model. ANN results conclude that feed rate is the most influential parameter which affects the surface of the work piece. In[7] developed a mathematical model to predict the cutting force and surface roughness of AISI52100 ally steel in hard turning under minimum quantity lubrication. Observed results showed good surface finish by increase in cutting speed, but at higher speed it in not significant.

In[8] studied the nano fluid usages in minimal cutting fluid technique of turning process. The output results shows reduced surface roughness are very encouraging with much reduction in surface roughness, tool flank wear, temperatures and cutting forces is observed in fluids with nanoparticle inclusions. From the past studies gave some important information about different methods of cooling systems adopted in machining operations and different models are developed for predicting the output factors. In this present work we utilized the combined form of artificial neural network and fuzzy logic system like adaptive neuro fuzzy system to predict the surface roughness of the H13 Tool steel in hard turning using minimal cutting fluid application.

3. Experimental Details

Based on the huge applications in area of hot forging, dies manufacturing, bending and blanking tools etc., the work piece with the dimension of diameter 70 mm and length 360 mm used for this research work is H13 tool steel of hardness 45 HRC. Mineral oil is used as the cutting fluid for this experimental work in minimum quantity only.

The photographic view of the experimental lathe setup used for this work is shown in the Figure 1. The input factors

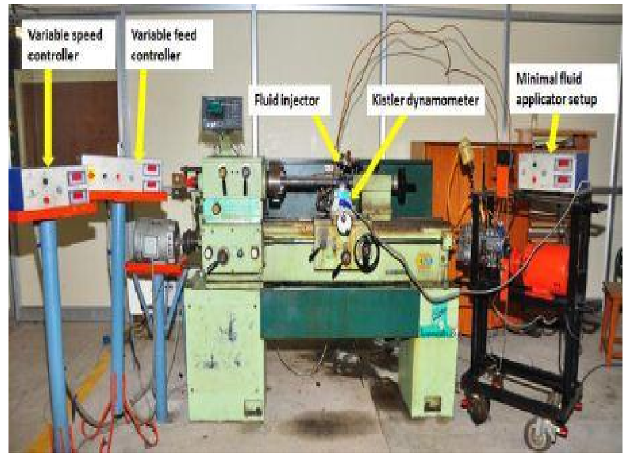

Figure 1. Experimental Setup.

consider for this current work is feed rate, speed and depth of cut. The fixed fluid parameters consider for this work is 100 bar fluid pressure, 500 pulses/min of frequency of pulsing and 30 % of mineral oil in water. The Taguchi design of experiment with three factors at three levels is used for designing the experiment. The different levels of the parameters are tabulated in the Table 1. For this, orthogonal array of L27 design is used. For all these 27 experiments surface roughness are measured by using SJ 210 portable surface roughness measurement instrument. The actual input parameters and the corresponding response surface roughness values are tabulated in the Table 2.

4. Adaptive Neuro Fuzzy Inference System

ANFIS is one of the excellent tradeoff between neural network and fuzzy systems. It has a set of adaptive networks that are functionally equivalent to fuzzy inference systems which uses a hybrid learning algorithm. The proposed ANFIS model with three input parameters and one output parameters consists of the following procedure for predict the process output parameters.

- Enter all the input values and their corresponding output response in the command window and then load all it in the ANFIS editor tool box which is mainly based on sugeno fuzzy model is shown in the Figure 2.
- Then based on the grid partitioned method the fuzzy inference system is generated.
- Typically, the membership function for this proposed fuzzy set can be parameterized membership function

Table 1. Levels of Process Parameters

Levels	Feed Rate (mm/rev)	Speed (m/min)	Depth of Cut(mm)
Minimum	0.05	75	0.5
Middle	0.075	95	0.7
Maximum	0.1	115	1

Table 2. Actual Responses for 27 Experiments

Sl. No.	Feed Rate (mm/rev)	Speed (m/min)	Depth of Cut (mm)	Surface Roughness (µm)
1.	0.050	75	0.50	1.28
2.	0.050	75	0.75	1.10
3.	0.050	75	1.00	1.58
4.	0.050	95	0.50	0.91
5.	0.050	95	0.75	1.03
6.	0.050	95	1.00	1.13
7.	0.050	115	0.50	1.38
8.	0.050	115	0.75	1.34
9.	0.050	115	1.00	1.45
10.	0.075	75	0.50	1.19
11.	0.075	75	0.75	1.09
12.	0.075	75	1.00	1.48
13.	0.075	95	0.50	1.45
14.	0.075	95	0.75	1.86
15.	0.075	95	1.00	1.82
16.	0.075	115	0.50	1.43
17.	0.075	115	0.75	1.70
18.	0.075	115	1.00	1.65
19.	0.100	75	0.50	1.64
20.	0.100	75	0.75	1.13
21.	0.100	75	1.00	1.78
22.	0.100	95	0.50	1.77
23.	0.100	95	0.75	1.83
24.	0.100	95	1.00	1.53
25.	0.100	115	0.50	1.32
26.	0.100	115	0.75	1.60
27.	0.100	115	1.00	1.79

is triangular. The architecture with three numbers of membership functions for this model is shown in the Figure 3.

- The selected membership function type output response is linear which is shown in the Figure 4.

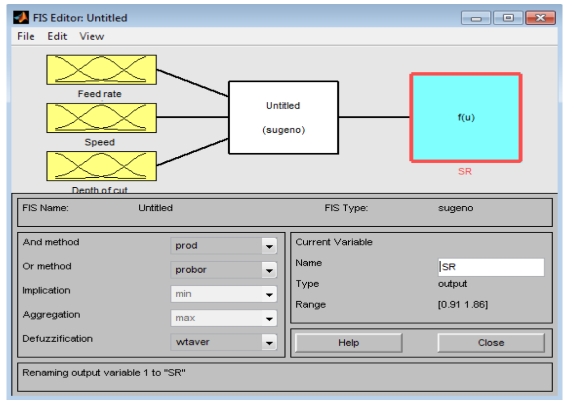

Figure 2. Proposed ANFIS Model.

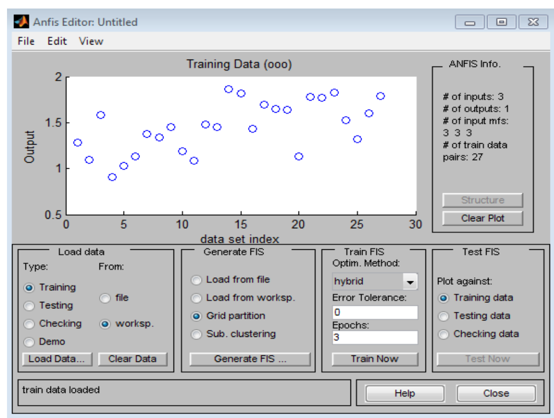

Figure 3. Plotting of Data.

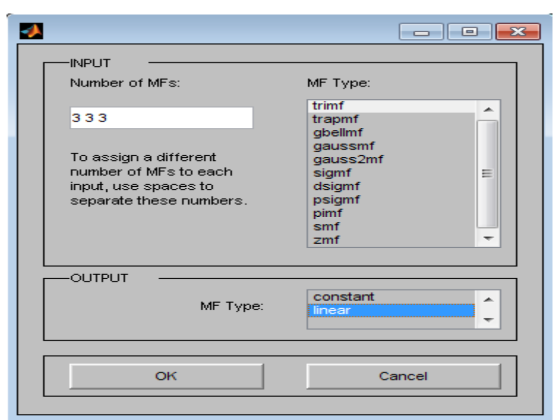

Figure 4. Selection of Membership Function.

- The model is trained with 50 numbers of epochs. During training process, the input and output parameters are adjusted and the error is minimized for each and every epoch. The error minimization is shown in the Figure 5.
- Then testing the data's using fuzzy inference systems which adopt their rules in a self-manner as shown in Figures 6-11 and predicted responses surface roughness values using ANFIS is shown in Table 3.

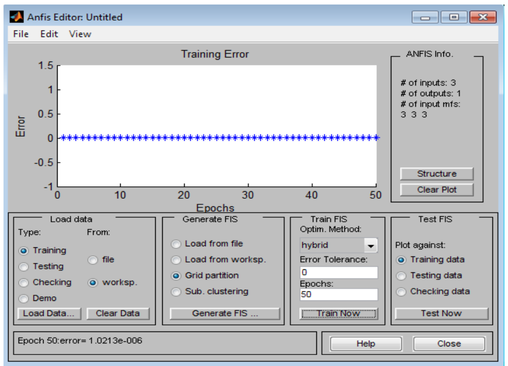

Figure 5. Training the Data Using Hybrid Type.

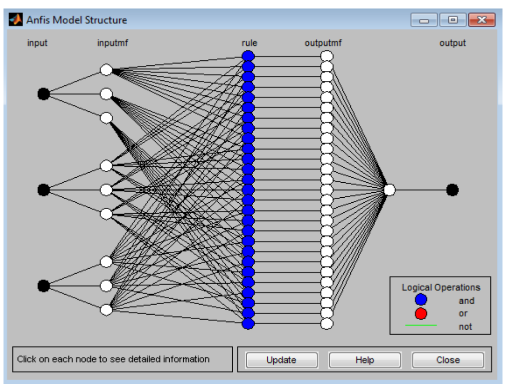

Figure 6. Developed ANFIS Structure.

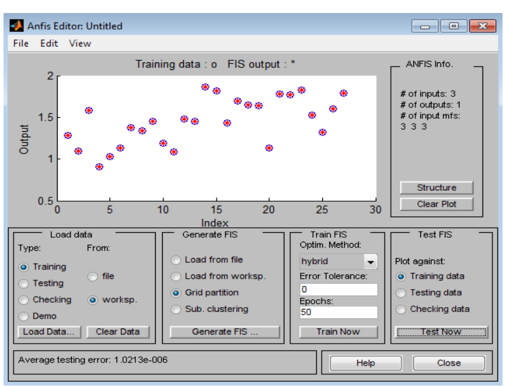

Figure 7. Plot between Actual and Predicted Responses.

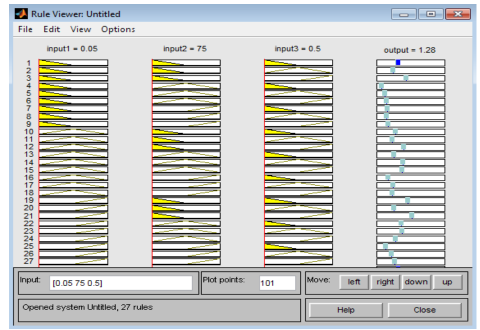

Figure 8. Rule Viewer for the Proposed ANFIS Model.

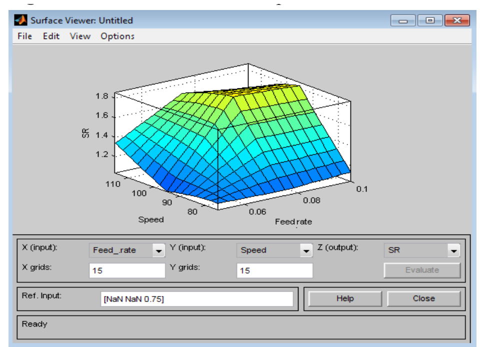

Figure 9. Surface Viewer for Feed Rate vs Speed.

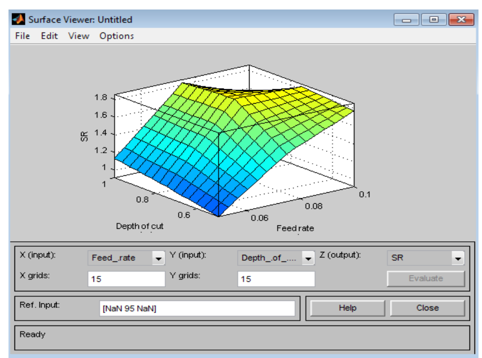

Figure 10. Surface Viewer for Feed Rate vs. Speed.

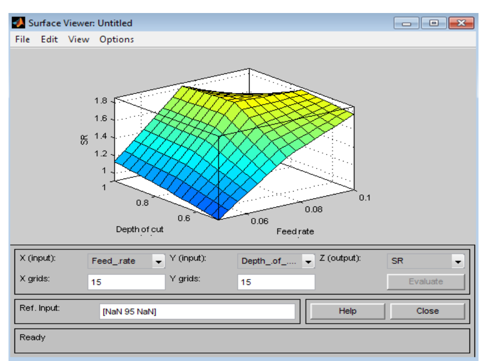

Figure 11. Surface viewer for Speed vs. Depth of Cut.

Table 3. Predicted Responses Using ANFIS

Sl. No.	Feed Rate (mm/rev)	Speed (m/min)	Depth of Cut (mm)	SR (µm)	Predicted SR (µm)
1.	0.050	75	0.50	1.28	1.28
2.	0.050	75	0.75	1.10	1.10
3.	0.050	75	1.00	1.58	1.58
4.	0.050	95	0.50	0.91	0.91
5.	0.050	95	0.75	1.03	1.03
6.	0.050	95	1.00	1.13	1.13
7.	0.050	115	0.50	1.38	1.38
8.	0.050	115	0.75	1.34	1.34
9.	0.050	115	1.00	1.45	1.45
10.	0.075	75	0.50	1.19	1.19
11.	0.075	75	0.75	1.09	1.09
12.	0.075	75	1.00	1.48	1.48
13.	0.075	95	0.50	1.45	1.45
14.	0.075	95	0.75	1.86	1.86
15.	0.075	95	1.00	1.82	1.82
16.	0.075	115	0.50	1.43	1.43
17.	0.075	115	0.75	1.70	1.70
18.	0.075	115	1.00	1.65	1.65
19.	0.100	75	0.50	1.64	1.64
20.	0.100	75	0.75	1.13	1.13
21.	0.100	75	1.00	1.78	1.78
22.	0.100	95	0.50	1.77	1.77
23.	0.100	95	0.75	1.83	1.83
24.	0.100	95	1.00	1.53	1.53
25.	0.100	115	0.50	1.32	1.32
26.	0.100	115	0.75	1.60	1.60
27.	0.100	115	1.00	1.79	1.79

5. Conclusion

The plotting of actual output surface roughness and the predicted output are placed centrally, which denotes there is no deviation in the predicted outputs. The predicted output which is obtained in the rule viewer shows there is no difference with the actual output. Surface viewer for all the three types clearly shows that the surface roughness value is reduced during the controllable parameters at low level. We suggest adaptive neuro fuzzy inference system with hybrid type is one of the excellent tools for future manufacturing works.

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