SURFACE ROUGHNESS PREDICTION IN CNC TURNING BASED ON MOTOR CURRENT USING ANFIS

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Abstract: In this study, Adaptive Neuro Fuzzy Inference System (ANFIS) is used to predict the Surface roughness from the motor currents of the Computer Numerically Controlled (CNC) lathe during turning of EN8 steel. Experimental data collected is used for training the ANFIS designed using MATLAB Neuro Fuzzy designer tool. The Fuzzy Inference System created has two inputs feed (mm/rev) and ΔI/z with three trapezoidal membership functions each. The results are discussed in the paper and the future work is stated.

Keywords: ANFIS, Surface Roughness, CNC lathe, Adaptive control, Motor current

1. INTRODUCTION

Maximizing the productivity has been the primary goal of manufacturing sector since the beginning. Along with the quantity improving quality is the challenging objective. In such perspective, surface quality depends on very dynamic parameters ignoring which might increase the chance of unacceptable surface quality. But, conservative selection of machining parameters such as speed, feed and depth of cut decrease the production rate. Even though the optimization techniques/algorithms are used before the beginning of machining process to find the optimum parameters, the machining conditions change with tool wear, temperature rise and other disturbances. Hence it is necessary to control the process parameters on-line during the process.

As it is difficult to measure the surface roughness during the machining, this paper focuses on the prediction of surface roughness parallel to the machining process. For this purpose as mathematical modelling of surface roughness is very complicated process, Artificial intelligence tool (ANFIS) is used to accomplish a relation between input machining parameters and surface roughness.

Xiaoli Li, Han-Xiong Li, Xin-Ping Guan and R. Du[1], in their paper developed an ANFIS model that can estimate the feed cutting force in turning process from the motor current and spindle speed with an accuracy of 95%. Darmus Karayel[2] in his work, developed an artificial neural network for the prediction of surface roughness and its variations with depth of cut, cutting speed and feed rate. Bandit Suksawat[3] used a mamdani type fuzzy inference system that determines the relation of cutting speed, feed rate and cutting force to the surface roughness and could predict the surface roughness with an accuracy of 87%. İlhan Asilturk and Mehmett Cunkas[4] have also worked on prediction of surface roughness in turning operation using ANN. In the paper produced by Ashwani Kharola [5] published in the International journal of recent advances in Mechanical Engineering Vol.4, No.3 in August 2015, the work is done on developing a hybrid Neuro-fuzzy controller for Surface Roughness prediction. F Čus et.al [6] in their paper mentioned that a correlation is found between cutting force and surface roughness and cutting force signals contained the most useful information in determining the surface roughness.

Hence as mentioned above research shows that the motor currents have a direct relation with the cutting force and cutting force is the major parameter for surface roughness. Hence this paper try to find the relation and explore the possibility of predicting surface roughness from the spindle motor current.

2. DETAILS EXPERIMENTAL

2.1. Materials and Procedures

The material used for this research is EN8 grade mild steel. CNC lathe machine present in the CNC lab of K J Somaiya College of Engineering, Vidyavihar, Mumbai is used for the experimentation. It is an ACE engineering make of type Jobber-XL. It is attached with a FUNAC AC spindle motor. Surface roughness test are carried out in ELCA laboratories, Thane, Mumbai on Handysurf E-35.

Surface roughness is to be estimated from the Spindle drive motor currents. As mentioned earlier, Surface roughness is majorly dependent on the cutting force and cutting force is directly related to the cutting current. Cutting current (ΔI) is the difference between total current (I) passing and the air cutting current (I_o). In the motor, total current can be measured using magnetic induction base clamp meter.

$$\Delta I = I - I_o$$

As we are trying to relate the surface roughness to the cutting force which induces the cutting torque on the motor and result in the increase of current passing through the motor, Increase in the current due to the load or torque is obtained by calculating the difference between the total current and air cutting current at the same speed (ΔI).

ΔI is directly related to the cutting torque hence by dividing with the z coordinate value which is twice the radial distance between center and the point where cutting force is acting on the tool, a value which is directly related to the cutting force i.e. ΔI/z. Power is supplied to the motor through the power cable from the cabinet present on rear side of the machine. The cable is traced for the three phase lines and a clamp meter is attached to one of the phases to measure the current. The clamp meter used in this experiment is of MECO made 27- Auto model.

2.2. Experiment

For the experiment, three levels of variables of speed, feed and depth of cut are taken as they all contribute in the change of cutting force, hence the cutting force and cutting current. Three levels are taken as follows and 27 readings of motor current are noted. This data is used in training ANFIS.

Table1: Parameter selection for experiment to obtain training data

Parameters	Level 1	Level 2	Level 3
Speed (RPM)	1000	1500	2000
Feed (mm/min)	60	120	180
Depth of cut (mm)	1	1.5	2

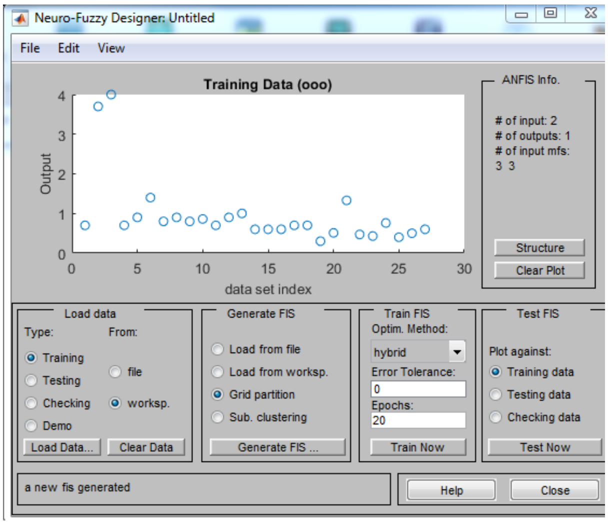

Fig.1. Loading input and output data collected by experiment in the Neuro-Fuzzy designer.

After loading the input and output data from the experiment into MATLAB, Neuro-Fuzzy Designer tool box, a Fuzzy inference system (FIS) is designed with two inputs and one output. Each input has 3 Trapezoidal membership functions and the structure of the FIS is shown in Fig.2. Training is done using a Hybrid learning process for 20 epochs. The average testing error is obtained to be 0.63416 after the training. This system can be used for further prediction of surface roughness by giving feed(mm/rev) and ΔI/z as inputs.

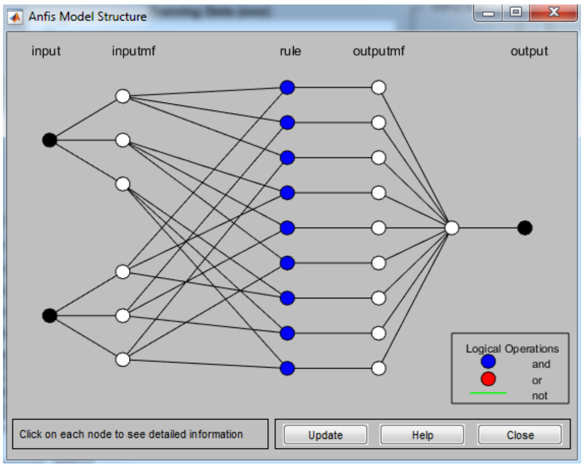

Fig.2. Structure of the FIS built.

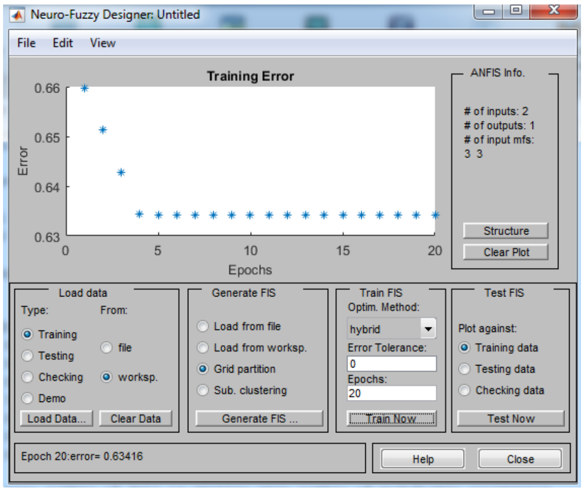

Fig.3. Training error after 20 epochs

3. RESULTS AND DISCUSSION

3.1. ANFIS Results

The above experiment to predict the surface roughness has shown decent results with the ANFIS tool and the surface view of the output is given in Fig.6.

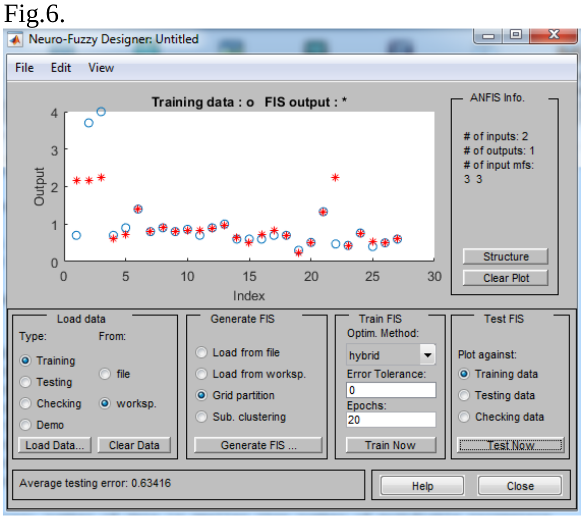

Fig.4. Comparison of training data against the predicted output.

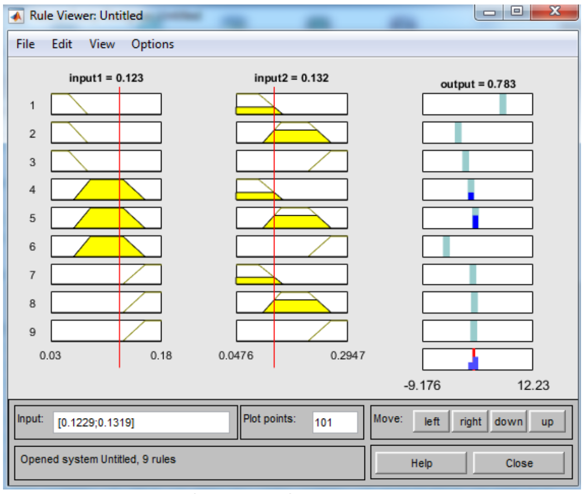

Fig.5. Rule viewer of the FIS after training.

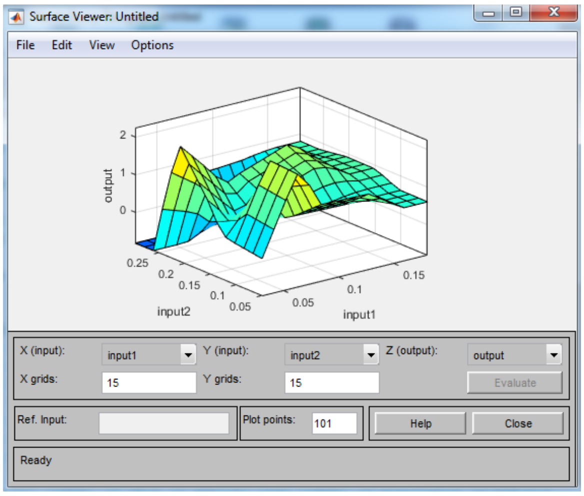

Fig.6. Surface viewer obtained after training.

3.2. Future work

Designed FIS will be tested by conducting another experiment where the specimens are machined and surface roughness predicted by the ANFIS will be compared with actual surface roughness measured by surface metre. An adaptive control system can also be designed that keeps the spindle load constant, in turn the motor current constant to achieve the desired surface roughness at maximum production rate possible.

CONCLUSIONS

An ANFIS to predict the surface roughness of EN8 mild steel in turning operation performed on CNC lathe is designed. The training and testing results are found satisfactory. Motor currents can be very important parameter in the prediction of surface roughness. The present model could achieve an average testing error up to 0.63416 and can be improved a lot by further research. It provides a large scope to achieve adaptive control and provide an economical solution for online prediction.

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