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PREDICTION OF CUTTING FORCE IN TURNING USING DESIGN OF EXPERIMENTS AND ARTIFICIAL NEURAL NETWORK

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ABSTRACT

The cutting force has a significant influence on the dimensional accuracy because of tool and work piece deflection in turning. Force modeling in metal cutting is important for a multitude of purposes, including thermal analysis, tool life estimation, chatter prediction, tool condition monitoring, etc. Cutting force plays a vital role in turning operation. Required surface finish and dimensional accuracy is based only on cutting force. Experiments were conducted in all geared head centre lathe on machining C 45 steel specimens using Carbide tipped cutter using Design of Experiments based on central composite method. Results obtained from the experiment were used to predict the cutting force with the help of mathematical model developed using Quality America software. Using the measured force an Artificial Neural Network (ANN) model was developed using MATLAB 7.0 software. ANN model architecture consists of single hidden layer with 5 hidden neurons and trained by using feed forward back propagation algorithm. In addition, the results obtained by experimental procedure and from ANN model were compared to confirm that the developed ANN is more accurate in prediction.

KEYWORDS : -Cutting Machine, Work Material, Measuring Equipments, MATLAB 7.0 software

INTRODUCTION

This work deals with the prediction of tangential and thrust force using mathematical model developed with the help of Design of Experiment (DOE) and Artificial Neural Network (ANN) for the corresponding input parameters viz. cutting speed, feed and depth of cut. To perform a turning operation with a high dimensional accuracy, cutting force plays a vital role. The conditions were created using a matrix, which allowed each factor an equal number of test conditions. Methods for analyzing the results of such experiments were also introduced. When the number of combinations possible became too large, schemes were devised to carry out a fraction of total

possibilities such that all factors would be evenly present. Fisher devised the first methods that made it
Possible to analyze the effect of more than one factor at a time.

OBJECTIVE FUNCTION

The purpose is to investigate the optimal cutting parameters for minimizing machining time of the turning operation while maintaining material removal rate and stability of the cutting process. The main parameters in machining affecting machining time are cutting speed, feed and depth of cut. The optimal cutting parameters are subjected to an objective function of minimum machining time with the feasible range of cutting parameters.

MATHEMATICAL MODEL

The response function representing any of the machining parameters can be expressed using the equation

$$Y = f(X_1, X_2, X_3) \quad \ldots\ldots\ldots$$

Where,

Y = Response or yield
X_1 = Cutting Speed (v) in m/min
X_2 = Feed (f) in mm/rev
X_3 = Depth of cut (d) in mm

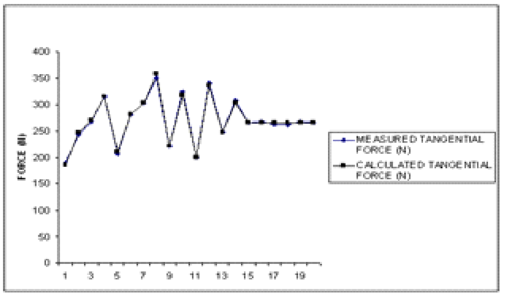
The second order response surface model for the four selected factors is given by the equation 3.2

$$Y = \beta_0 + \sum_{i=1} \beta_i X_i + \sum_{i=1} \beta_{ii} X_i^2 + \sum_{i<j} \beta_{ij} X_i X_j \ldots\ldots\ldots\ldots \qquad (3.2)$$

The second order response surface model [equation 3.3] could be expressed as follows

$$Y = \beta_0 + \beta_1 v + \beta_2 f + \beta_3 d + \beta_1 1 v^2 + \beta_{22} f^2 + \beta_{33} d^2 + \beta_{12} vf + \beta_{13} vd + \beta_{23} fd \ldots.. \quad (3.3)$$

Where β0 is the free term of the regression equation, the coefficients β1, β2 and β3 are linear terms, the coefficients β11, β22 and β33 are the quadratic terms, and the coefficients β12, β13 and β23 are the interaction terms. The coefficients were calculated using QA six sigma software (DOE-PCIV).



Comparison of Measured and Predicted Tangential force values
Comparison of Measured and Predicted Thrust force values

Comparison of Measured and Predicted Tangential force values

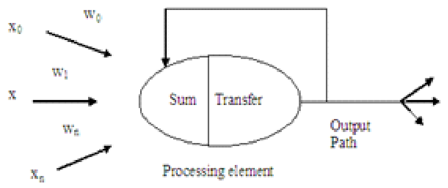
Comparison of Measured and Predicted Thrust force values

Design matrix value and responses (three factors, five levels)						
Design of matrix				Cutting force(thrust)		Percentage error (%)
Ex. no	Cutting speed	Feed	Depth of cut	Measured	Calculated	
1	-1	-1	-1	120	116.84	2.62
2	+1	-1	-1	160	162.75	1.72
3	-1	+1	-1	178.14	180.86	1.52
4	+1	+1	-1	214.02	214.19	0.08
5	-1	-1	+1	132.37	135.02	2

Comparison of Measured and Predicted Tangential force values
Comparison of Measured and Predicted Thrust force values

Confirmation tests were conducted in the same experimental setup to confirm the results of the experiment and demonstrate the reliability of the predicted values. The conformity tests show the accuracy of the models developed, which is above 95%.

Basic Artificial Neuron



Artificial Neural Network (ANN)

Artificial neural networks are massive parallel-interconnected networks that consist of basic computing elements called neurons interconnected via unidirectional signal channels called connection that imitates the human brain. Each processing element has a single output connection that branches into as many collateral connections as desired. The most widely used technique, the feed forward back propagation neural network, is adapted for the prediction of tool wear and surface roughness in the turning operation.

Artificial Neurons And How They Work

The fundamental processing element of a neural network is a neuron. This building block of human awareness encompasses a few general capabilities. Basically, a biological neuron receives inputs from other sources, combines them in some way, performs a generally nonlinear operation on the result, and then outputs the final result.

TYPES OF ANN

Basically there are two types of ANN
1. Supervised Networks
2. Unsupervised Networks

Feed Forward Back Propagation Network

A feed forward back propagation network consists of an input layer (where the inputs of the problem are received), hidden layers (where the relationship between the inputs and outputs are determined and represented by synaptic weights) and an output layer (which emits the outputs of the problem).

Matlab Software

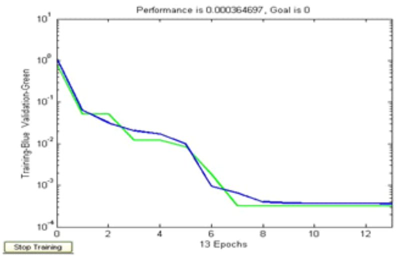
MATLAB stands for MATrix LABoratory developed by The Mathworks Incorporation, USA and is an interactive system for matrix-based computation designed for scientific and engineering use. It is good for many forms of numeric computation and visualization.

Results of ANN

Number of input nodes	3
Number of hidden nodes	5
Number of output nodes	2
Type of learning method	Supervised learning
Algorithm	Feed forward Back propagation
Learning rule	Gradient descent rule
Number of learning patterns used	20
The leaning parameter used	0.5
Number of epochs	1000

Comparison of Measured and Predicted Tangential force values

Ex no	Cutting speed (m/min)	Feed (mm/rev)	Depth of cut (mm)	Calculated tangential force (N)	Predicted tangential force (N)	% error
1	82.5	0.097	0.2	190	193.24	-1.705
2	127.5	0.097	0.2	242.78	239.84	1.210973
3	82.5	0.152	0.2	267.52	267.38	0.052333
4	127.5	0.152	0.2	315.36	320.44	-1.61086
5	82.5	0.097	0.4	206.5	209.66	-1.53027



ANN Performance Training Graph

CONCLUSIONS

We can say that for turning operation the dimensional accuracy depends on the cutting force. The cutting force can be predicted by the ANN and the maximum percentage difference is listed below.

The maximum percentage difference between measured and predicted tangential force using ANN model is obtained at the experiment no 7. The input parameters, output parameters and the % deviation at the experiment no 7 are given below

Cutting speed = 82.5 m / min
Feed = 0.152 mm / rev
Depth of cut = 0.4 mm
Measured tangential force value =303.81 N
Predicted tangential force value =309.38 N
Percentage deviation =1.833 %

The maximum percentage difference between measured and predicted thrust force is obtained at the experiment no 2. The input parameters, output parameters and the % deviation at the experiment no 2 are given below

Cutting speed = 127.5 m / min
Feed = 0.097 mm / rev
Depth of cut = 0.2 mm
Measured thrust force value =160 N
Predicted thrust force value =157.265 N
Percentage deviation =1.70 %

The compared result confirms that the developed ANN model is more accurate in prediction.

REFERENCES:

1. Hassan Gokkaya and Muammer Nalbant (2005) "The effects of cutting tool coating on the surface roughness of AISI 1015 steel depending on cutting parameters" Turkish Journal of engineering and environmental science, Vol. 30, pp.307-316.
2. Kumanan.S,.Nanne Saheb.S.K and Jesuthanam.C.P (2006), "Prediction of machining forces using Neural Networks Trained by a Genetic Algorithm" Journal of industrial engineering, Vol. 87, pp.11-15.
3. Tugrul Ozel, Tsu- Kong Hsu (2004), " Effects of cutting edge geometry, workpiece hardness, feed rate and cutting speed on surface roughness and forces in finishing turning of hardened AISI H13 steel" International Journal of Advanced Manufacturing Technology, Vol. 25, pp.262-269.