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ANN MODELING FOR PREDICTION OF CUTTING FORCE COMPONENT DURING ORTHOGONAL TURNING

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Abstract: - *Turning is the process of extensive stress and deformation. Calculation of the cutting force acts as the potential ground work for the evaluation of the force required in turning and for designing, selecting the cutting tool. Cutting force depends on many factors i.e. machining parameters. In this paper a MATLAB software code based interface is developed to estimate the effect of cutting parameters on cutting force and an ANN model is trained in MATLAB neural network tool with experimental measured output as training dataset and predicted the influence of cutting conditions on cutting force. Here a conventional center lathe, HSS cutting tool with -10^{o} back rake angle and mild steel with 227.37 BHN hardness is used for experimentation, speed, feed rate and depth of cut are the parameters considered. Results shows that the parameters considered have significant effect on cutting force, as the feed rate increases cutting force will also increase and as depth of cut value increases then also cutting force will increase. It conclude that the developed MATLAB code based interface and ANN model will gives precise results so this software based models can be used in future for estimation and prediction of experimental results which will save time and cost.*

Keywords: *Cutting Parameters, cutting force MATLAB, GUI, and ANN.*

1. Introduction

Metal cutting and forming are the most normal manufacturing practice from the old ages. Machining process has been used for a long time, yet researches on machining began just during nineteenth century. A lot of examination has been coordinated towards to know the influence of cutting parameters on cutting forces and for prediction, estimation and measurement of cutting forces.

Rodriguez L.L.R et.al.

In this study mild steel in turning is used to estimate the effect of operating parameters on surface condition and cutting force. ANOVA and full factorial methods were taken for determination. HSS tool is exercised. Outcomes shows that surface quality and force are more affected by feed rate, while speed has negligible effect. Depth of cut influences the cutting force but not the surface condition.

Dr. C J Rao et.al.

This work reports the importance of speed, feed and depth of cut on cutting force and surface roughness while machining with ceramic tool with an Al_2O_3+TiC composite (KY1615) and the work material of AISI 1050 steel (hardness of 484 HV). Investigations were performed utilizing Johnford TC35 Industrial CNC machine. Taguchi technique (L27 design with 3 levels and 3 variables) was utilized for the investigations. Examination of difference with adjusted approach has been adopted. The outcomes have shown that it is feed rate which has critical impact both on cutting force and also surface roughness. Depth of cut impacts cutting force however has an unimportant impact on surface roughness. The connection of feed and depth of cut and the interaction of all the three cutting parameters have critical impact on cutting force, while, none of the connection impacts are having noteworthy impact on the surface roughness produced.

Ashish Yadav et.al.

Work is done on optimization of turning process parameter for their effect on EN 8 material work-piece by using Taguchi parametric optimization method. Mainly focused on investigating the relation between change in hardness caused on the material surface due to turning operation with different machining parameters (spindle speed, feed and depth of cut). EN8 material with carbide coated tool is used. Hardness after turning is measured on Rockwell scale. From this study the relationship as mentioned above is developed. S/N ratio technique of Taguchi method is used for analysis the experimental data. Effect of various process parameters are calculated for getting the results.

Jagadesh T and Samuel GL.

It is worked on development of 3D oblique FEM for prediction of cutting forces, thrust forces, feed rate and tool chip interface temperature during micro turning. Titanium (Ti6Al4V) and coated carbide tool (TiN/ Al TiN) is taken as work and tool respectively. Johnson-cook material model with strain gradient plasticity is used to show the flow of stress. Results show that cutting edge radius is influencing on magnitude of cutting force and style of material removal, heat generated is dominated at high speed which make the material to soft etc.

P Venkataramaiah et.al.

In this work the influence of feed rate and tool geometry on cutting forces during turning is experimented by Taguchi method and Fuzzy logic. Number of iterations of Taguchi experimental design on aluminium work piece with HSS tool having variable geometry at different feed rate, cutting force is recorded. Orthogonal array model is designed with 3 factors at four levels using MINITAB software. A Fuzzy model system is developed to estimate the result obtained by Taguchi method. Output shows that for optimal value of feed rate, cutting force and radial force optimal conditions are identified. ANOVA test results also used to show the relationship between effects of parameters.

J. Paulo Davim et.al.

In this research, free machining steel (free cutting steel) 9SMnPb28K(DIN) is used in turning to study the surface roughness quality which is affected by cutting condition by ANN model with cemented carbide insert tool. Ra & Rt are the surface condition parameter developed and feed rate, cutting speed and depth of cut are the affecting process parameters. L27 orthogonal array with three levels defined to get the dataset for ANN with error back propagation training algorithm (EBPTA), 3D plots are developed using ANN to study the behavior of cutting parameters on surface roughness. By this analysis it is observed that cutting speed & feed rate have significant effects, i.e. surface roughness reduction and depth of cut has less effect

2. Development of Models

2.1 Programming

MATLAB uses high level language to write the program. In this work for interface execution, programs have to be written in script widow of MATLAB. For writing programs many MATLAB scripts and database of required parameters are created and formulas are used to get the results.

Formulas used in program

According to loladze, the main cutting force for orthogonal turning can be calculated as

$$Fc = \tau_s \times f \times d((\cos(\beta-\alpha))/(\sin\phi \times \cos(\phi+\beta-\alpha)))$$

Where,

Fc = Tangential force/ main cutting force in N (Newton's)

τ_s = shear stress in N/mm2

f = feed rate in mm/rev

d = depth of cut in mm

β = friction angle in degree, (^{o})

α = tool rake angle in degree, (^{o})

$\emptyset$ = shear angle in degree, (^{o})

2.1.1 Creating user interface dialog box

First taking all the cutting parameters essential for cutting force estimation, the user interface dialog box is developed in MATLAB as shown if fig.2.1.

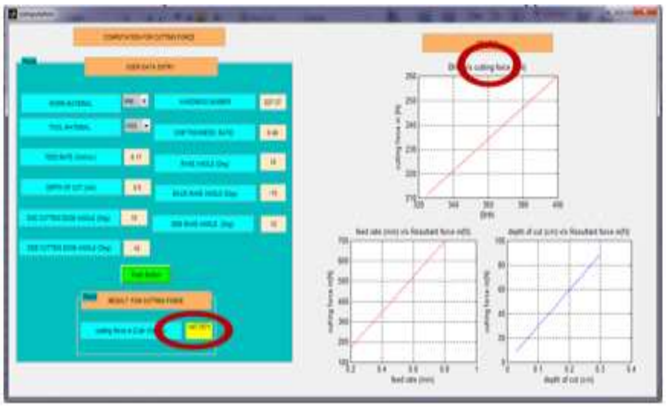

Fig 2.1 UI with Output result and Graphs

In this user interface the user has to give required input data (cutting parameters) which is necessary for cutting force calculations. Input parameters like work material, tool material, feed rate, depth of cut, different tool angles, chip thickness ratio and hardness of the work material have to be entered in UI. After entering these values push button in UI has to be clicked this will give a result and graphs as shown fig. 2.1. with the help of the background program written in MATLAB.

2.2 Artificial Neural Network - Introduction

Artificial neural network (ANN) approach is a robust method for approximating real-valued, discreet valued and vector valued target functions. It is one among the accurate learning methods presently available. The research of ANN was inspired by the neurobiological learning system, which have interdependent neuron of complex webs. Biological neuron has many inputs and output sets and it can have excited or non-excited sets of outputs and it depends on the attenuation in the synapses, these are the joining paths of neurons. Below fig.2.2 shows an active node of artificial neural network.

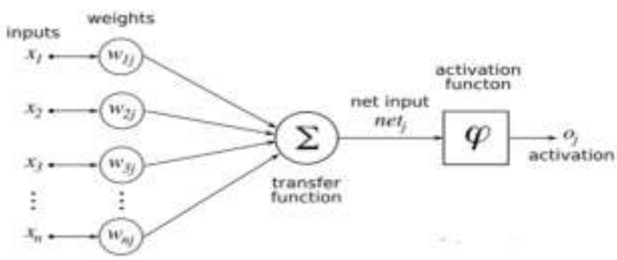

Fig 2.2 Neural network active node

6.2.2 Building ANN: Procedure for Prediction

The way that ANN has an ability to solve problems with non-linearity, it has been broadly used by the researchers. Thus in this work ANN is used to model and predict the cutting force during orthogonal cutting. The number of layers in ANN is decided by the complexity and nature of problem. Normally there are three layers in ANN namely input layer, output layer and hidden layer, where input and output layers are the first and last layers respectively.

The hidden layer calculates input data from input layer. Similarly, the second hidden layer processes the output and final result is given by output layer. Transfer function is used to calculate the final result.

The structure used in modeling ANN is shown in Fig 2.3

Training is the basic step in ANN. Input parameters and target output data from experimentation is used as trauning data. Back prapogation algorithm is used to minimize the error to attain satisfactory level of performance. When the required performance level is achieved network traing is stopped.In this present work, neural network toolbox from MATLAB was emplyoed for ANN modeling, training and validation. The training data set for ANN training is shown in Talbe:3.1 & 3.2. number of iterations were performed to get required solution with initial random weights, training is terminated when minimum MSE is reached.

After reaching the required training level, the network was used to predict the cutting force for validation and testing. The ANN output results are shown in Fig. 2.4. The comparision of ANN model predicted outputs and experimental values are shown in Fig.4.1 & 4.2. and also table. 4.1 & 4.2 shows the values of comparision of cutting force at constant feed rate and depth of cut respectively.

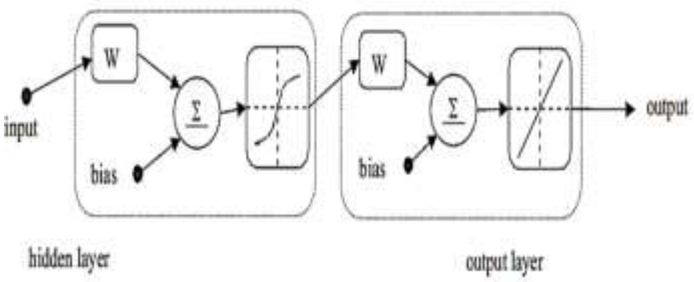

Fig 2.3 Neural network Structure used for modeling

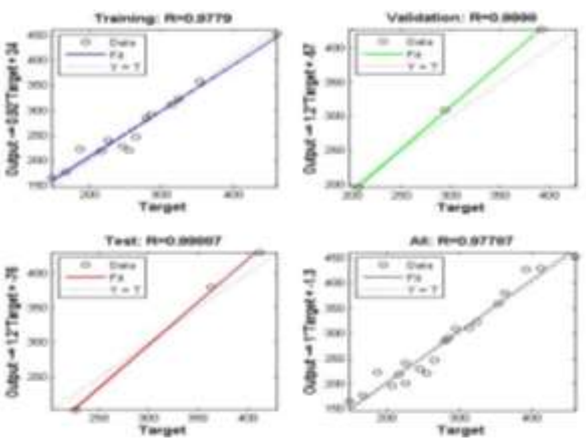

Fig 2.4 Output from ANN

3. Experimentation

Experimental strategies are mostly practiced in research and also in industrial setup, but the purposes are different sometimes. The basic aim of organized investigation is normally to demonstrate statistical denotation of consequences that a specific aspect applies on reliant variable of interest. To observe the effect of depth of cut, feed rate and cutting speed experiments were conducted considering orthogonal cutting.

Machine tool: Conventional Centre lathe machine

Work-piece material: Mild Steel with 20mm diameter and 227.37 BHN.

Tool material: HSS-M2, 20×20×100 mm

Dynamometer used: Strain gauge type three component digital lathe tool dynamometer.

Fig 3.1 Experimental setup

Different cutting conditions have been considered as listed in Table 3.1 & 3.2.

Table 3.1 Experimental data of main cutting force with constant feed rate.

SPEED (RPM)	FEED (mm/rev)	DOC (mm)	Tangential cutting force (N)
90	0.17	0.5	156.46
90	0.17	0.7	196.25
90	0.17	0.9	215.86
90	0.17	1.1	274.68
90	0.17	1.3	309.01
270	0.2	0.5	166.77
270	0.2	0.7	235.4
270	0.2	0.9	274.68
270	0.2	1.1	294.3
270	0.2	1.3	343.35
540	0.23	0.5	196.25

540	0.23	0.7	255.06
540	0.23	0.9	313.9
540	0.23	1.1	372.4
540	0.23	1.3	412.02

Table 3.2 Experimental data of main cutting force with constant depth of cut.

SPEED (RPM)	DOC (mm)	FEED (mm/rev)	Tangential cutting force (N)
90	0.5	0.17	147.15
90	0.5	0.2	166.77
90	0.5	0.23	206.01
90	0.5	0.26	225.63
90	0.5	0.29	255.06
270	0.7	0.17	186.39
270	0.7	0.2	225.63
270	0.7	0.23	264.87
270	0.7	0.26	279.58
270	0.7	0.29	323.73
270	0.9	0.17	215.82
270	0.9	0.2	284.5
270	0.9	0.23	294.3
270	0.9	0.26	353.16
270	0.9	0.29	392.4
540	1.1	0.17	245.25
540	1.1	0.2	313.92
540	1.1	0.23	362.97
540	1.1	0.26	412.02
540	1.1	0.29	461.07

4. Results and Discussion

The MATLAB interface and ANN model so build can be used for analyzing the effects of the selected cutting parameters on cutting force.

In order to determine the effects of turning process parameters on cutting force, the two-dimensional plots were generated considering all parameters. These result effects are shown in Figs. 4.1 & 4.2 and compared with different methods of estimation.

Table 4.1: Cutting force at constant Feed Rate.

Speed (rpm)	FEED (mm/rev)	DOC (mm)	Exp. Cutting force (N)	Predicted cutting force ANN(N)	Estimated cutting force (N)
90	0.17	0.5	156.46	156.68	147.75
90	0.17	0.7	196.25	196.52	189.2
90	0.17	0.9	215.86	215.85	227.92
90	0.17	1.1	274.68	274.67	262.25
90	0.17	1.3	309.01	309.03	297.01
270	0.20	0.5	166.77	169.06	173.83
270	0.20	0.7	235.40	234.14	222.59
270	0.20	0.9	274.68	267.66	268.15
270	0.20	1.1	294.30	293.67	308.53
270	0.20	1.3	343.35	348.35	349.43
540	0.23	0.5	196.25	224.75	199.90
540	0.23	0.7	255.06	261.15	255.98
540	0.23	0.9	313.90	322.81	308.37
540	0.23	1.1	372.40	366.01	354.81
540	0.23	1.3	412.02	410.1	401.84

From the below fig.4.1 it's observed that as depth of cut increases the force required for cutting also increases because thickness of chip becomes more important. Hence as depth of cut increases cutting force also increases. Also cutting force predicted from ANN model and estimated from MATLAB code are very close to the experimental values.

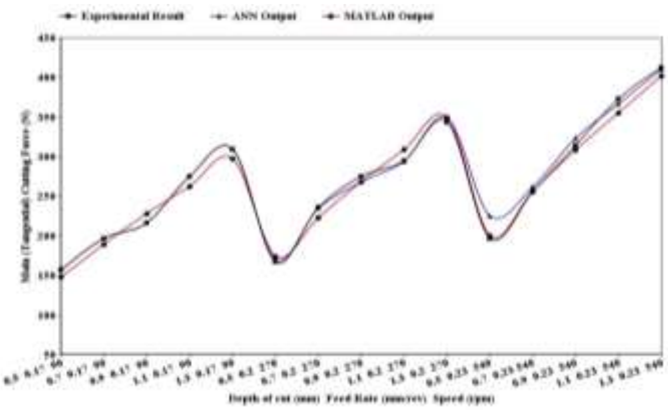

Fig 4.1 Cutting force at constant Feed rate

Table 4.2 Cutting Force at Constant depth of cut

Speed (rpm)	DOC (mm)	FEED (mm/ rev)	Exp. Cutting Force(N)	Predicted cutting force ANN (N)	Estimated cutting force MATLAB (N)
90	0.5	0.17	147.15	148.10	147.75
90	0.5	0.20	166.77	170.18	173.83
90	0.5	0.23	206.01	202.42	199.9
90	0.5	0.26	225.63	225.45	225.98
90	0.5	0.29	255.06	254.7	252.05
270	0.7	0.17	186.39	182.8	189.2
270	0.7	0.20	225.63	227.02	222.59
270	0.7	0.23	264.87	260.17	255.98
270	0.7	0.26	279.58	264.18	289.37
270	0.7	0.29	323.73	312.06	322.76
270	0.9	0.17	215.82	215.66	227.92
270	0.9	0.20	284.5	280.68	268.15
270	0.9	0.23	294.3	289.70	308.37
270	0.9	0.26	353.16	348.22	348.59
270	0.9	0.29	392.4	410.53	388.81
540	1.1	0.17	245.25	244.26	262.25
540	1.1	0.20	313.92	336.70	308.53
540	1.1	0.23	362.97	359.95	354.81
540	1.1	0.26	412.02	405.42	401.09
540	1.1	0.29	461.07	451.94	447.37

From the below fig.4.2 it's observed that as feed rate increases the force required for cutting also increases because chip shearing becomes more important. Hence as feed rate increases cutting force also increases. Also cutting force predicted from ANN model and estimated from MATLAB code are very close to the experimental values.

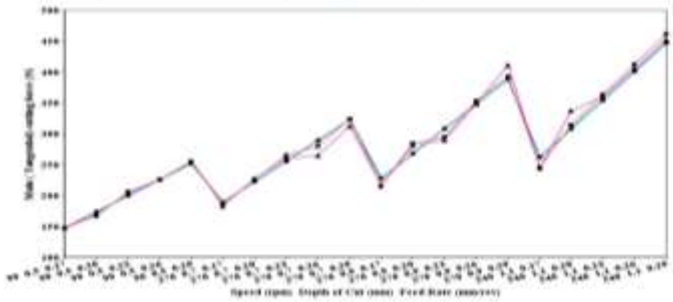

Fig 4.2 Cutting force at constant depth of cut

From above figs.4.1 & 4.2 the as speed range is small the cutting force will increase as speed increases but from literature it is studied that force will increase only to certain limit and start reducing as speed increases.

5. Conclusion

From the results it can be seen that cutting parameters have significant effect on cutting force. As feed rate increase cutting force also will increases and cutting force will also increase with increase in depth of cut and speed.

The developed MATLAB interface and ANN model gives minimum error with comparison with experimental values so this developed models in future can be used to estimate and predict the cutting force without costly experimentation.

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