DEVELOPMENT OF GENETIC PROGRAMMING MODEL FOR PREDICTION OF CUTTING FORCES IN ROTARY MILLING

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Abstract - There has been huge requirement and immense interest to develop the novel technologies in the metal machining and defence industry because of the improvement of tool substances reached optimalstage. The cutting tool life was drastically reduced while machining ofdifficult to cut materials such as titanium based super alloys; Nickel based super alloys and structural composite materials. Here the novel technology to increase tool life is self propelled rotary machining. The manufacturers were developing such tools to increase the productivity. In this work face milling operation was carried out on Inconel 625 a Nickel based super alloy which is widely consumed in industries like aerospace and defence. After conducting experiments predictive models were developed using multi gene genetic programming (MGGP) to predict the cutting force. The cutting force which is predicted using MGGP had the better correlation with the experimental values.

Keyword - Rotary machining, MGGP, Inconel 625, Nickel based super alloys.

I. INTRODUCTION

Machining of difficult to cut materials like titanium alloys, nickel based super alloys and structural composites in aerospace, defence and metal cutting industry is challenging to the researchers and manufacturers because of the excessive tool wear. The development of rotary tools is one of the novel techniques to overcome the tool wear problem. There is a speedy evaluation of modern materials like nickel and titanium alloys with enhanced characteristics like strength to weight ratio, the complexity in cutting of these alloys effectively and financiallyare restrict the applications of these materials. The investigations to develop modern tool materials are at final stage. The manufacturers of all over the world are concentrated on advanced designs of tools. One such design is the rotary machining i.e. self propelled rotary turning and selfpropelled rotary milling operations in which the life of the tool is drasticallyimprovedand advancedalloys can be machined more rapidly at lower cost of the cutting toolcompared totraditionaltools [1-6]. Depending on the literature, the experiments were investigated only on rotary turning and on rotary milling there is a limited focus. A model to the cutting force was developed by Baro (2005) for self propelled rotary milling cutter while investigating rotary face milling. [7]. There is limited investigations were performed on advanced materials which are widely used in aerospace industrial applications.

Hence there is a requirement for futurestudies in the process of rotary milling particularly while machining advanced and improved materials which are widely used in aerospace industry.The presentresearch, a rotary face milling cutter with four inclination angles was developed and the cutting capability was investigated on Inconel 625.

The working capability of the new designed self propelled milling tool while machining Inconel 625 a Nickel based superalloys is investigated through conducting experiments using design of experiments. To predict the cutting force a soft computing model was developed in rotary face milling using Multi-gene genetic programming (MGGP) technique and it was validated. The experimentswere conducted on Inconel 625with coated carbide round insert. These investigationswereconducted based on full factorial technique.

II. EXPERIMENTATION



Fig: 1. Cutter for Rotary Face Milling

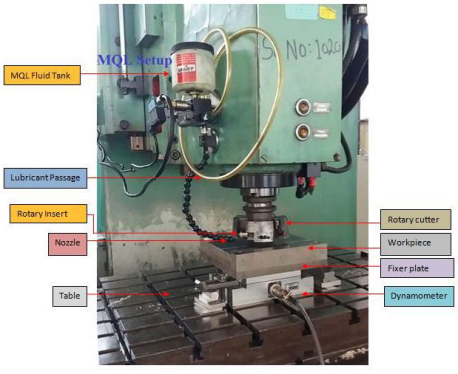


Fig: 2. Experimental Setup

Fig: 1. shows the designed and developed rotary milling cutter which was used for experimental investigations on Inconel 625.

The cutting force was measured using a six component dynamometer (make: AMTI, USA). The work piece is fixed over the dynamometer and then the generated cutting force was captured through a data acquisition system. The fig. 2 shows the experimental setup. Table 1 shows the composition of Inconel 625.

Table 1: Composition ofthe work material i.e. Nickel based superalloy Inconel 625

Nickel	58 %	Niobium	3.15%	Phosphorus	0.015%
Chromium	23%	Carbon	0.10%	Sulfur	0.015%
Molybdenum	10%	Manganese	0.50%	Aluminum	0.40%
Iron	5%	Silicon	0.50%	Titanium	0.40%
Cobalt	1.0%				

2.1. Methodology

The primary experimentations were carried out to measure cutting force, based on the full factorial design using Design expert.

The experimental investigations were carried out for three times and the average of three values was taken as cutting force in X direction, Y direction and Z direction. The full factorial experimental investigation was conducted to estimate the effectiveness of cutting variables on the cutting force in all the three directions. The levels of the cutting variables are shown in the below Table.2.

Table2.Full factorial experimentation levels of Process Variables.

Process Variables	Units	Levels			
		1	2	3	4
Inclination angle (I)	Deg	20	30	40	50
Speed (S)	m/min	14	24	34	-
Feed (F)	mm/min	40	60	80	-
Depth of Cut (D)	mm	0.2	0.4	0.6	-

2.2. MGGP model for Cutting force

A soft copmuting technique is developed to achieve optimal values of cutting force using MGGP. The MGGP was developed using MATLAB package (GpTIPS Toolbox). MGGP –is an intelligence algorithm MGGP uses a hybrid algorithm for training the data and obtain the computing models.

The hybrid algorithm has the following characteristics like of Genetic algorithm, Back Propagation and Least squares. MGGP approach offers a process for the GP modelling procedure to achieve information about a data set. Fig. 3 presents the steps to be followed for generate an MGGP model.The last step of the flow chart is generally called as validation of the model. Fig 4 shows the MGGP model structure.

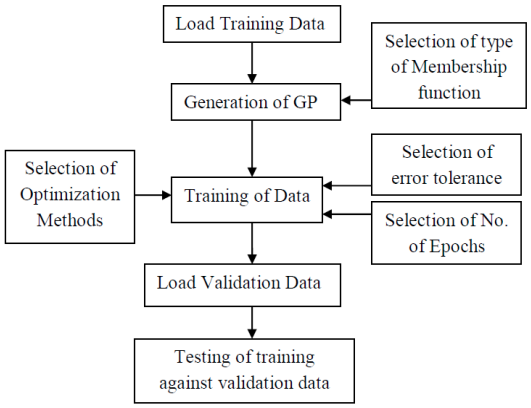
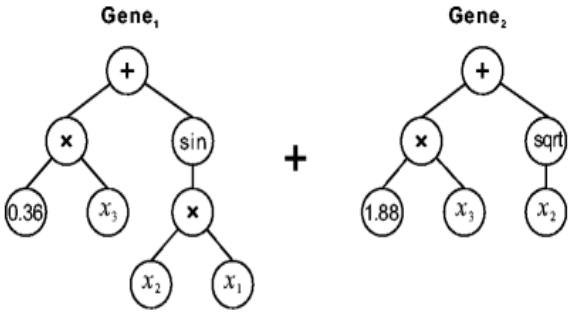


Fig.3. Flow chart for MGGP procedureFig.4. MGGP model structure



MGGP model:

$$y = d_0 + d_1(0.36x_3 + \sin(x_2 \times x_1)) + d_2(1.88x_3 + \mathrm{sqrt}(x_2))$$

III. RESULTS AND DISCUSSION

The Figs. 5 to 7 are shows the deviations of experimentally investigated cutting forces and the predicted cutting forces for the data which is obtained by conducting full factorial experimentation to develop the MGGP model. The MGGP model gives the average deviations is 6%, 5% and 7% for X, Y and Z directions.

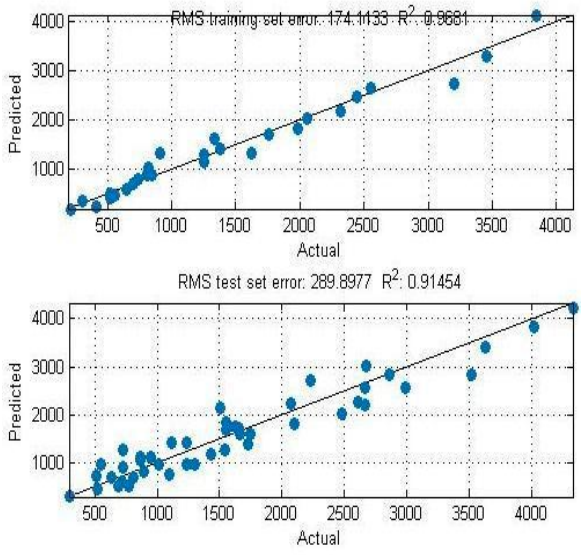


Fig. 5 (a) Performance scatter plot for MGGP Regression model for Fx

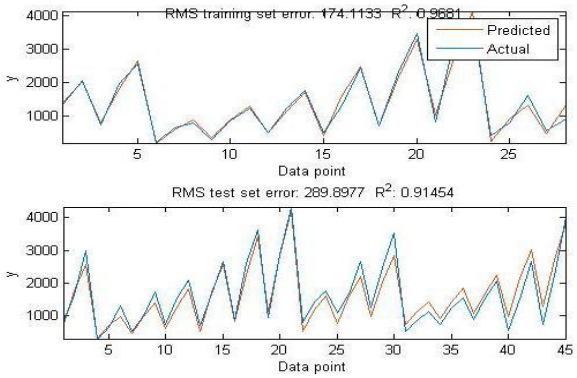


Fig. 5 (b).Comparison of predicted model and experimental value at all data points of Fx

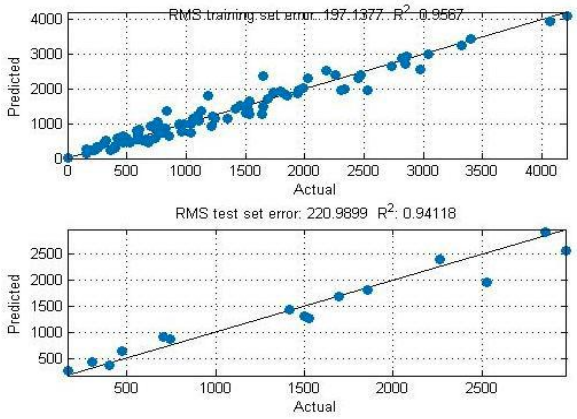


Fig. 6 (a) Performance scatter plot for MGGP Regression model for Fy

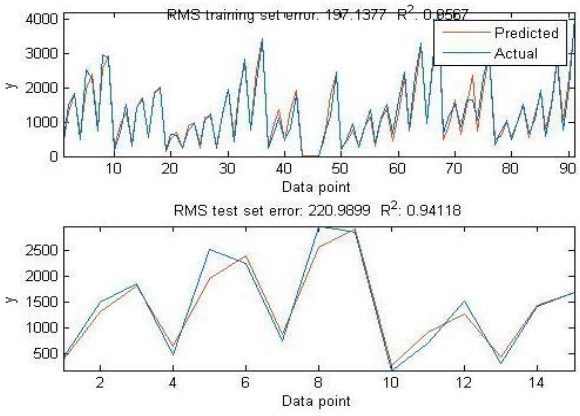


Fig. 6 (b).Comparison of predicted model and experimental value at all data points of Fy

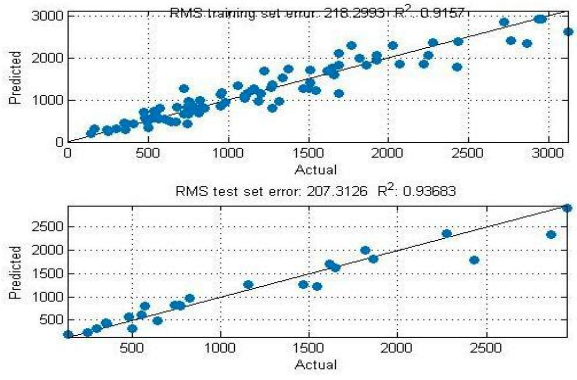


Fig.7 (a) Performance scatter plot for MGGP Regression model for Fz

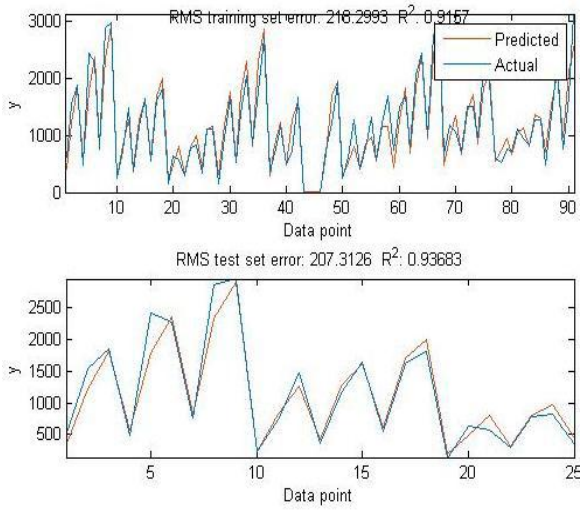


Fig. 7 (b).Comparison of predicted model and experimental value at all data points of Fz

3.1 MGGP and regression ModelsPrediction capability

The cutting force correlation coefficients (CC) generated using MGGP model and regression models were shown in the below table. 3. By observing the table. 3, it is clearly stated that the MGGP model was the excellent predictable for the cutting force outside the trained data.

Table.3. Comparison of the correlation coefficients

Cutting Force	CC for regression Model	CC for MGGP Model
F_x	0.92	0.96
F_y	0.91	0.95
F_z	0.85	0.91

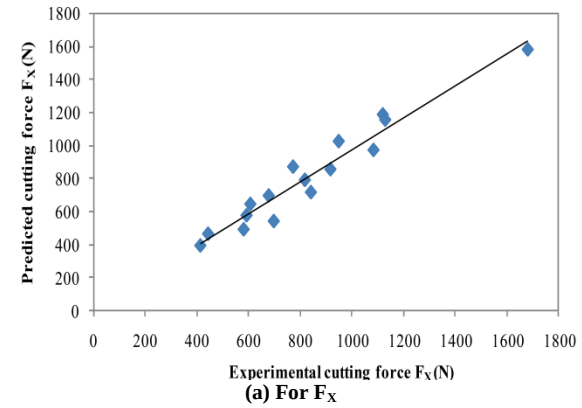
A total of 108theoritical investigatiosn were conducted on inconel 625 and taken as data inputs to the MGGP model. These data points were taken as three groups namely training set, testing set and validation set. From all these data sets, 70% of data is utilized as trainimg set, 15% is for testing set and remaining 15% is for validation set. Majarity data points should be utilized forteraining set for better training of the model.

The training procedure come to an end each time the selected number is accomplished that is 10 for this particular process. After training the MGGP model, using the validation set the model was validated.

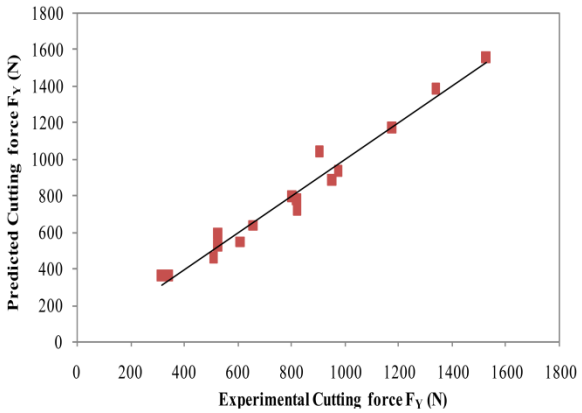
3.2MGGP modelValidation

The model of MGGP was validated by the validationset. 10% of 108 data points are 10 data points, which are utilized for validation.

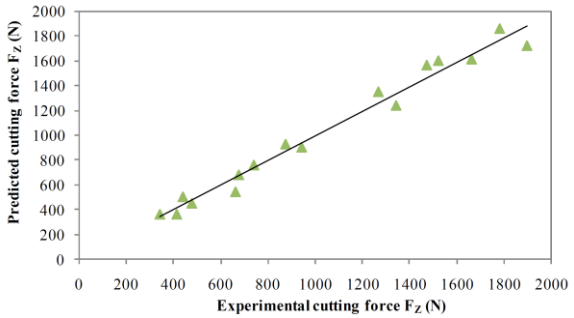
The results of cutting forces for the combination of cuttingvariables in validation set is compared with the experimental cutting forces for the same set. The Fig. 8 shows the comparission of experimental and predicted cutting forces.



(a) For F_X



(b) For F_Y



(c) For F_Z

Fig.8. (a), (b) & (c) Comparission ofMGGP model Correlation coefficients

The predicted cutting force results of rotary milling were trained based on the erlier discussions and compared with the experimenal results of cutting force acquired using full factorial investigations and the variation in the predicted values are to be23.4%, 23.1% and 26.8% for X, Y and Z directionsrespectively.

CONCLUSIONS

The soft computing model of the cutting force acieved through the rotary face milling process while machining Inconel 625 was estimated and validated. Validation has expressed good agreement between the experimental and predicted results. The comparision between the MGGP model and regression model was predicted. Depending on this comparision, the prediction potential of MGGP is perfect. A data set of variousiterations of cutting variablesareestimatedthrough the theoretical model and is used to train and generate the MGGP model. The generated MGGP model is then evaluated with the experimental data and good agreement has been found between theexperimental and predicted values.

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