ISSN 2393-865X

INTERNATIONAL JOURNAL OF R&D IN ENGINEERING SCIENCE AND MANAGEMENT

Research Paper

MATHEMATICAL MODEL FOR SURFACE ROUGHNESS OF 2.5D MILLING USING FUZZY LOGIC MODEL.

AMIT VATS[a], Dr. ARUN KUMAR GUPTA[b], NAVEEN KHATAK[c]
[a]M.tech Scholar, Dept. of Mechanical Engg., University Institute of Engg. & Tech., Rohtak
[b]Dept. of Mechanical Engg., Vaish College of Engg., Rohtak
[c]Dept. of Mechanical Engg., University Institute of Engg. & Tech., Rohtak

ABSTRACT

Milling is one of the complex machining processes in nature due to large variation in different responses as a result of dynamics of different input parameters.

The most of components developed by different milling processes gets mate with some another component and posses relative motion with each other. The smoothness in motion of these components are therefore highly depends upon the surface roughness. Hence, in the present work an attempt has been made to develop the surface roughness model for different milling parameters such as step over, feed, spindle speed and depth of cut using Fuzzy methodology. The learning of fuzzy model has been made by performing certain experiments based on the Taguchi L-18 orthogonal array. The machining has been performed on 54 mild steel blocks at different combination of input parameters. The Fuzzy logic model has been ruled with the help of the experimental results. The Mamdani fuzzy approach has been applied to predict the surface roughness. Further another rogation model has also been developed with the help of same experimental results to compare the performance of Fuzzy logic model. With the help of detailed analysis it has been found that the fuzzy logic based model gives more realistic results as compared to the regression model.

Keywords: Milling parameters, Mamdani fuzzy approach ,Taguchi, Mild steel blocks

1. Introduction

The smoothness in motion of two different components is highly depends on surface roughness of these components. The surface roughness also becomes very important for different types of tool and dies. Besides this, the life of a mechanical machine is also highly influenced by the surface roughness. The working of components like gears, cams, bearings, bushes and slides are highly depends upon the surface roughness of mating surfaces. Hence, to minimize the surface roughness, an accurate mathematical model is required. Therefore in the present work an attempt has been made to understand the characteristics of surface roughness with respect to the different machining parameters. Numerous researches have been performed to develop the realistic surface roughness model.

The statistical techniques such that Regression, Response surface methodology, Taguchi etc. are being applied very frequently by the researchers. Besides theses techniques, artificial intelligent techniques such as artificial neural network, Support vector machining, Fuzzy logic methodology and their combinations are more popular now a days. These techniques give better accuracy and provide good results for wide range of input parameters. The techniques are also provide better results for large number of input responses. Benardos and Vosniakos (2002) predicted surface roughness during CNC face milling using ANN and Taguchi design of experiments. Ghani et al. (2004) found optimal

Corresponding Author's email: amittvats@gmail.com

combination of machining parameters for low resultant cutting force and good surface finish using TM, S/N ratio and ANOVA. Ozcelik et al. (2005) used response surface methodology and ANN to predict surface roughness, where as the optimization problem is solved by GA. Kadirgama et al. (2007) developed the model for predicting the surface finish using statistical methods. The results have also been verified experimentally. Ginta et al. (2009) and Yazdi et al. (2010) used quarter factorial central composite design (CCD) RSM to create an efficient analytical model for surface roughness in terms of cutting speed, axial depth of cut and feed per tooth. Mustafa (2011) predicted surface finish and force models by using TM and regression analysis for milling of welded regions. The S/N ratio analysis was also applied to optimize the machining parameters for the objectives. Chandna & Gupta (2013) suggested an optimization strategy using Genetic Algorithm (GA) to solve the surface roughness optimization problem and the results had been compared with handbook recommendations.

In the present work an attempt has been made to develop the surface roughness model for different milling parameters such as step over, feed, spindle speed and depth of cut using Fuzzy methodology. The learning of fuzzy model has been made by performing certain experiments based on the Taguchi L-18 orthogonal array. The machining has been performed on 54 mild steel blocks at different combination of input parameters. The Fuzzy logic model has been ruled with the help of the experimental results. The Mamdani Fuzzy approach has been applied to predict the surface roughness. Further another rogation model has also been developed with the help of same experimental results to compare the performance of Fuzzy logic model.

2. Research methodology

The machining has been performed on 54 mild steel blocks at different combination of input parameters as per L18 orthogonal array as shown in table 1and different levels of input parameters have also been tabulated in table 2. A surface roughness model has been developed for different milling parameters such as step over, feed, spindle speed and depth of cut using Fuzzy Logic methodology.

Table 1 An L18 Taguchi orthogonal array

SR NO.	Levels of Step Over	Levels of Feed	Levels of Speed	Levels of DOC
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	1	1	1	1
5	1	2	2	2
6	1	3	3	3
7	1	1	1	1
8	1	2	2	2
9	1	3	3	3
10	2	1	1	1
11	2	2	2	2
12	2	3	3	3
13	2	1	1	1
14	2	2	2	2
15	2	3	3	3
15	2	3	3	3
16	2	1	1	1
17	2	2	2	2
18	2	3	3	3

The learning of fuzzy model has been made by performing certain experiments based on the Taguchi L-18 orthogonal array. The Fuzzy logic model has been ruled with the help of the experimental results. The Mamdani fuzzy approach has been applied to predict the surface roughness. Further regression model has also been developed with the help of same experimental results to compare the performance of Fuzzy logic model. The complete methodology is shown in figure 1 and table 3 illustrate the cutting tool, work piece and machine tool specifications.

Table 2 Milling process parameters and their levels

	Step Over in mm	Feed in mm/tooth	Speed m/min	D.O.C. In mm
Level 1	40	0.1	60	0.1
Level 2	50	0.2	70	0.2
Level 3		0.3	85	0.3

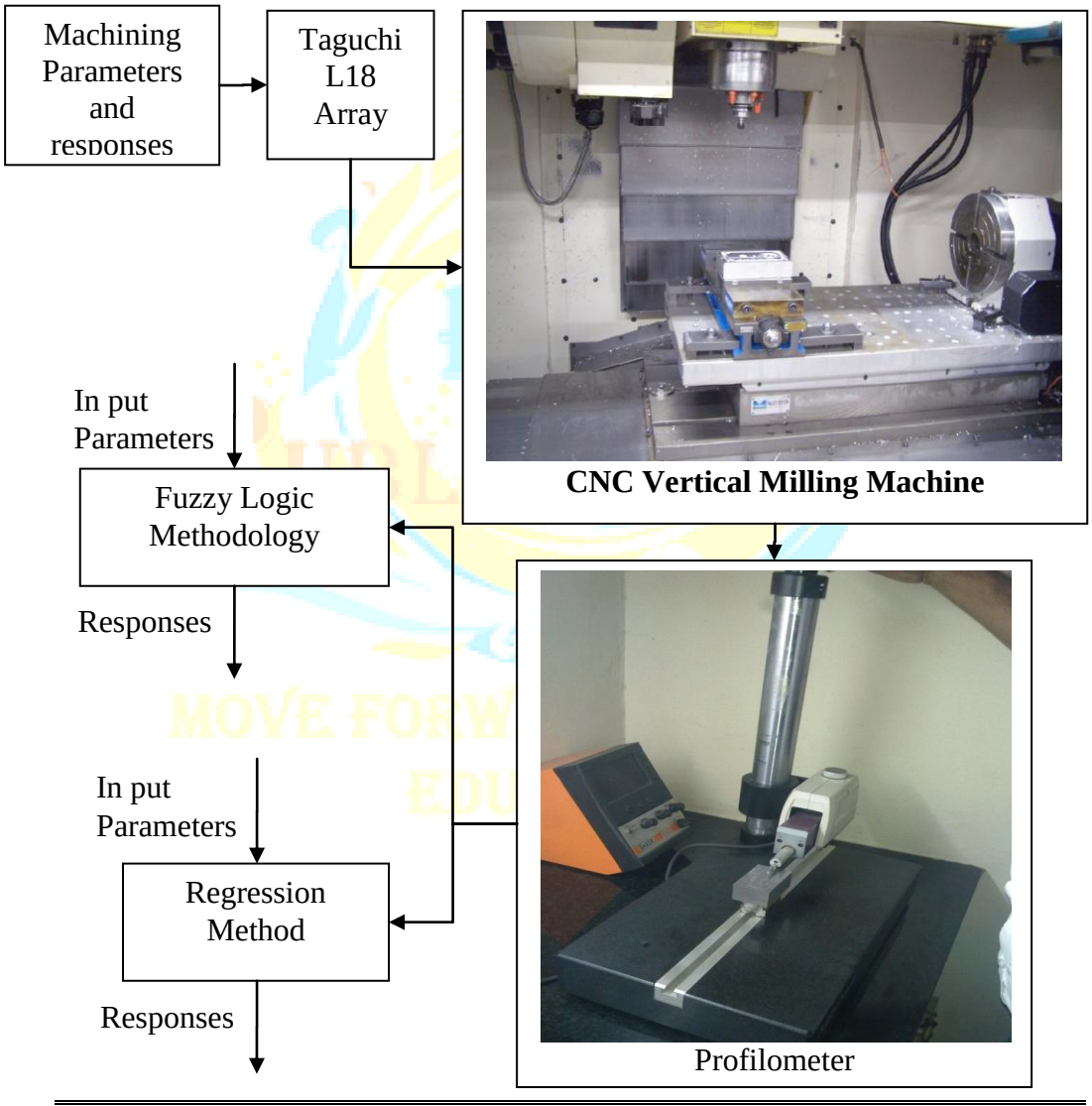

Figure 1 Flow diagram for research methodology

Table 3 Specification

	Work piece	Tool	Machine Specification
Type	Material Mild steel	Material Carbide	Fanuc controlled VMC
Sizes/specification	60mmx40mmx20mm	4 flutes, D=12mm	Table Size600X200

3. Fuzzy Logic methodology (FLM)

A fuzzy logic methodology (FLM) approach depends upon the certain rules. These rules are trained with the help of experiments. The input and output data of these experiments is inserted in the form of crisp values. These crisp variables are fuzzyfied into linguistic variables such as low, medium high. The different input parameters have been assigned triangular membership function. In fuzzy system, model is in the form of IF-THEN rule instead of mathematical equation. Fuzzy system consists of a fuzzifier, an inference engine, a database, a rule base and a defuzzifier. As shown in figure 2.

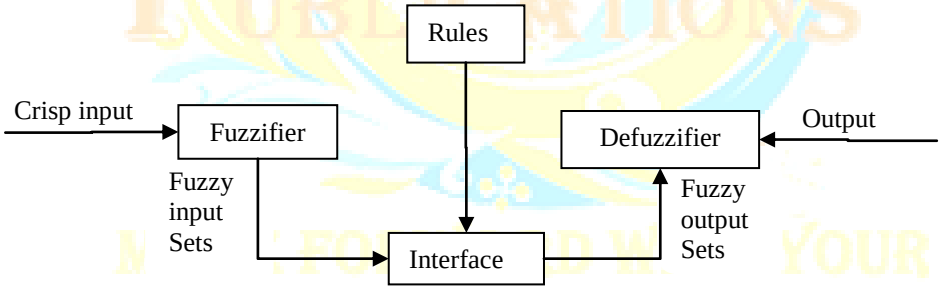

Figure 2 fuzzy Inference systems

Fuzzyfication Here in this research input parameters (DOC, Speed, Feed) are fuzzified in to three levels of linguistic terms (fuzzy sets) i.e. low medium high, where STEP OVER is fuzzified in two levels low and high as shown in table 4 .

Table 4 Different levels of machining parameters

Machining Parameters	Level 1	Level 2	Level 3	Level 4	Level 5
Step Over	LOW	HIGH	--------	--------	--------

Depth of Cut	LOW	MEDIUM	HIGH	--------	--------
Speed	LOW	MEDIUM	HIGH	--------	--------
Feed	LOW	MEDIUM	HIGH	--------	--------
Ra	VERY LOW	LOW	MEDIUM	HIGH	VERY HIGH

Triangular membership function is simple to used and computationally efficient. It requires only three parameters to define and is a function of vector x that depends on three parameters a, b and c. as shown below

$$f(a,b,c) = \begin{cases} 0, & x \le a \\ \frac{x-a}{b-a}, & a \le x \le b \\ \frac{c-x}{c-b}, & b \le x \le c \\ 0, & c \le x \end{cases} \quad (1)$$

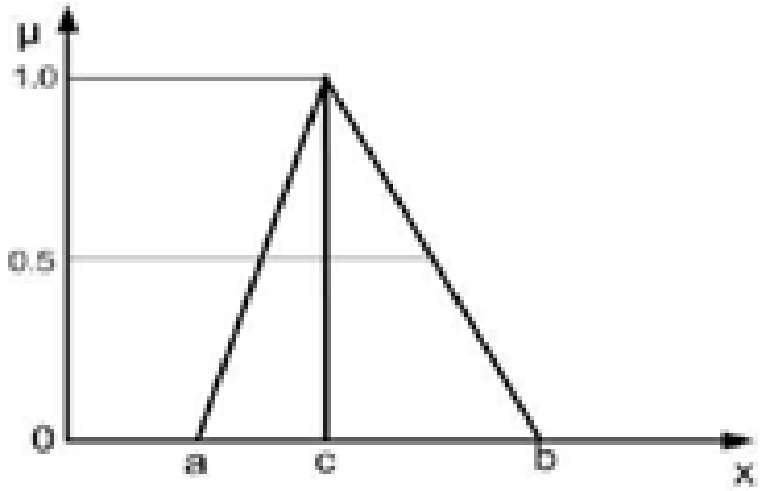

Figure 3 Triangular membership function

The value of membership function varies from 0 to 1, and this shows how much a variable matches the fuzzy sets. Triangular membership function for input//output parameters.

In this study step over, depth of cut, spindle speed and feed are considered as input parameter where surface roughness is considered as output parameter, fuzzy inference system for this study can be shown by figure 4.

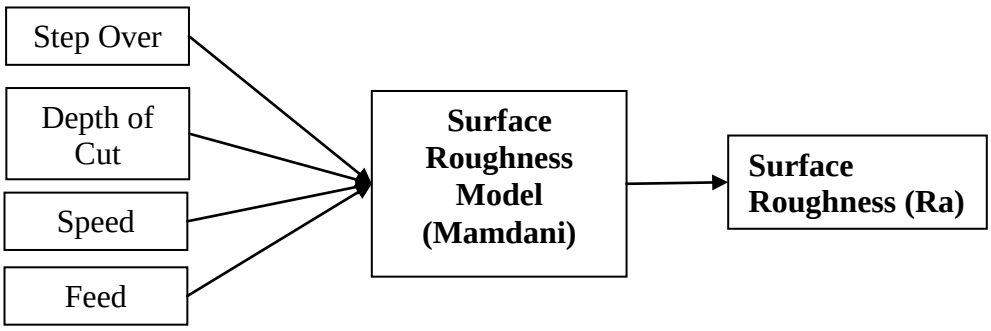

Figure 4 Fuzzy Inference System

In previous studies researchers concentrated of only three parameters these were speed, feed and depth of cut, but they neglected the importance of step over in machining. Where step over is a very important parameter for the study of any machining process. Therefore, step over also been considered along with these three input parameter.

Evaluation of Rules Application of the fuzzy logic rules on the membership function. Various rules are generated with the help of experimental data. By running these rules in MATLAB software graphical mathematical model has been developed, in which evaluation of surface roughness at different values of input parameters has been obtained by altering the values of input parameters.

As shown in figure 5.

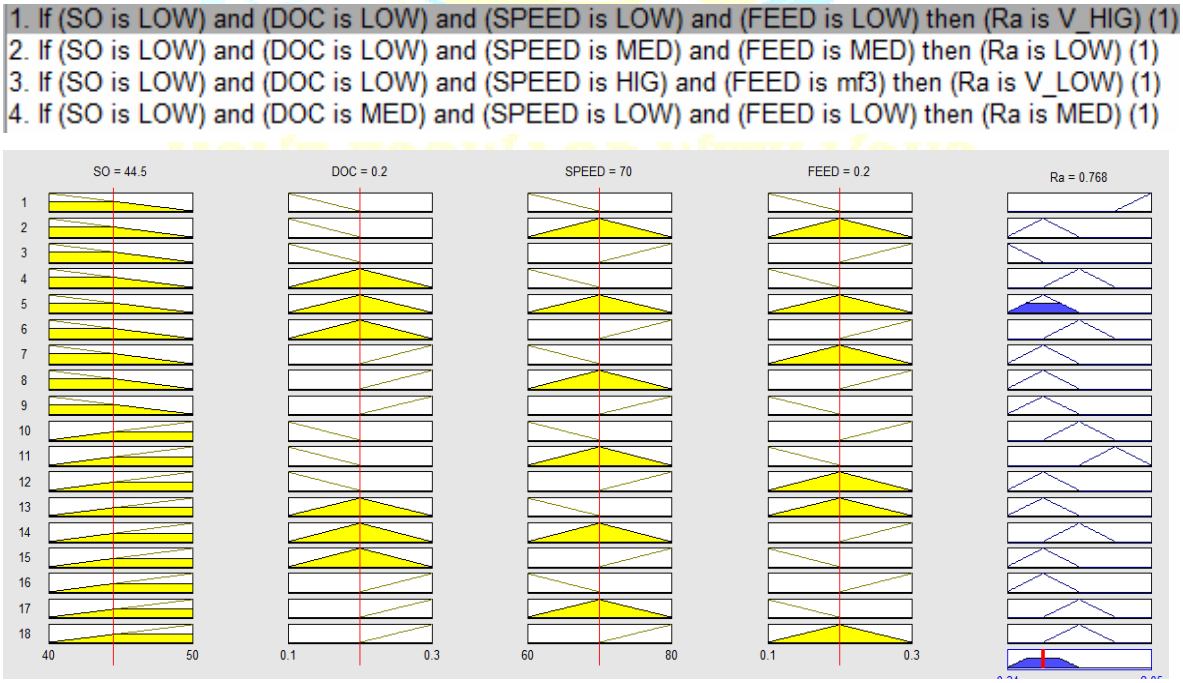

Figure 5 Graphical Representations of Fuzzy Rules

4. Regression analysis

For comparison of fuzzy logic methodology the surface roughness has also been estimated with help of regression analysis. A regression analysis is a statistical procedure used to find relationships among a set of variables. Regression analysis explains the variation in a dependent variable using the variation in independent variables. If the independent variables sufficiently explain the variation in the dependent variable, the model can be used for prediction. a linear polynomial model has been developed using Taguchi L-18 experimental array to control the roughness data using MINITAB statistical software. This linear polynomial is shown by eq (2).

$$Ra = b_0 + b_1(SO) + b_2(DOC) + b_3(Speed) + b_4(Feed) + \varepsilon \qquad (2)$$

Where b1, *b*2, *b*3, and b4 are the coefficient of the process input parameters, and ε is error. A mathematical equation is then derived to describe the functional relationship between the roughness (*Ra)* and process parameters *step over (SO), depth of cut (DOC), SPEED and FEED.*

The final regression relation between input and output is

$$Ra = 1.64 + 0.0116(SO) - 0.95\ (DOC) - 0.00846\ (Speed) - 1.83(Feed) + \varepsilon \qquad (3)$$

From this mathematical equation we can calculate the results for any input within the given range.

5. Results

Initially 54 experiments have been performed on CNC VMC with different combinations of input parameter as suggested by L18 orthogonal array and surface roughness is measure with the help of contact type profilometer. Three experiments have been performed for each combination of input parameter and the results obtained are shown in table 5. The prediction by the statistical method i.e. the regression and artificial intelligent method i.e. fuzzy logic methodology have also been tabulated in the same table.

Effectiveness of any mathematical model depends on the factor that how much it is nearer to the actual value. Therefore, Standard Error has been applied for prediction made by regression analysis and fuzzy logic methodology.

Table 5 Experimental Results

SO	DOC	Speed	Feed	R1	R2	R3	MEAN1	Reg.	Fuzzy
40	0.1	60	0.1	2	2.05	2.03	2.026667	1.318	1.91
40	0.1	70	0.2	0.65	0.7	0.66	0.67	1.051	0.767
40	0.1	85	0.3	0.35	0.34	0.37	0.353333	0.783	0.477
40	0.2	60	0.1	1.23	1.25	1.26	1.246667	1.223	1.190
40	0.2	70	0.2	0.68	0.67	0.64	0.663333	0.956	0.767
40	0.2	85	0.3	1.21	1.2	1.24	1.216667	0.688	1.190
40	0.3	60	0.2	0.64	0.71	0.68	0.676667	0.945	0.767
40	0.3	70	0.3	0.58	0.64	0.66	0.626667	0.678	0.767
40	0.3	85	0.1	0.88	0.93	0.96	0.923333	0.959	0.767
50	0.1	60	0.3	1.22	1.25	1.28	1.25	1.068	1.190
50	0.1	70	0.1	1.48	1.57	1.45	1.5	1.350	1.620
50	0.1	85	0.2	0.77	0.82	0.86	0.816667	1.082	0.767
50	0.2	60	0.2	0.55	0.58	0.6	0.576667	1.156	0.767
50	0.2	70	0.3	1.24	1.23	1.2	1.223333	0.889	1.190
50	0.2	85	0.1	0.78	0.77	0.82	0.79	1.170	0.767
50	0.3	60	0.3	0.78	0.85	0.88	0.836667	0.878	0.767
50	0.3	70	0.1	1.02	1.13	1.2	1.116667	1.160	1.190

50	0.3	85	0.2	1.25	1.033	1.28	1.286667	0.892	1.190

Standard error = $\sqrt{\frac{(o)-p)^2}{(n)}}$

Where, o is observed value,

P is predicted value and n is number of experiments.

Using the above formula of standard error for fuzzy and regression method,

The overall standard errors for fuzzy logic methodology and regression analysis are 0.1008 and 0.3456 respectively. Therefore from the results it has been observed that fuzzy logic methodology predicts 70.83% better than regression analysis.

7. Conclusions

In the end of this study we came to the conclusion that surface roughness can be predicted with the help of both of these rules. This study presents a combined application of the fuzzy logic method and the Taguchi orthogonal arrays to develop a robust mathematical model for surface roughness and the results have been compared with regression analysis. On comparison both the methods, it has been concluded that fuzzy logic provides better result as compared to the linear regression analysis by 70.83 for the surface roughness of milling operation problem.

References

[1] Chandna, P and Gupta, A K (2013) 'Optimization of Machining Parameters for Surface Roughness during 2.5D Milling' 2nd Industrial and Systems Engineering World Conference; Las Vegas, NV, USA.

[2] Ghani, J.A., Choudhury, I.A. & Hassan, H.H. (2004). Application of Taguchi method in the optimization of end milling parameters. *Journal of Material Processing Technology*, 2004; 145: 84-92.

[3] Mustafa, A. (2011). Determination and optimization of the machining parameters of the welded areas in moulds. *Journal of Scientific Research and Essays*, 2011; 6(2): 485-492Tsai, Y.H., Chen, J.C. & Lou S.J. (1999). In-process surface recognition system based on neural networks in end milling cutting operations. *International Journal Machine Tool Manufacturing*, 1999; 39 (4): 583-605.

[4] Yazdi, M.R.S. & Khorram, A. (2010). Modeling and optimization of milling process by using RSM and ANN methods. *International Journal of Engineering and Technology*, 2010; 2(5): 474-485.

[5] Ozcelik, B. and Bayramoglu, M. (2006). 'The statistical modeling of surface roughness in high-speed flat end milling'. *International Journal of Machine Tools & Manufacturing*, 2006; 46: 1395-1402.

[6] Benardos PG and Vosniakos GC, (2002) "Prediction of surface roughness in CNC face milling using neural networks and Taguchi's design of experiments," Robot Comput Integr Manuf, vol. 18, no.5/6, pp. 343–354,.

[7] Ozcelik, B., & Bayramoglu, M. (2005). 'The statistical modelling of surface roughness in high-speed flat end milling' International Journal of Machine Tools and Manufacture, vol 46, pp. 1395–1402.

[8] Wen-Hsien Hoa, Jinn-Tsong Tsai , Bor-Tsuen Lin & Jyh-Horng Chou(2009) 'Adaptive network-based fuzzy inference system for prediction of surface roughness in end milling process using hybrid Taguchi-genetic learning algorithm' Expert Systems with Applications vol. 36 pp. 3216–3222

[9] E. Zalnezhad and Ahmed A.D. Sarhan (2014) ' A fuzzy logic predictive model for better surface roughness of Ti–TiN coating on AL7075-T6 alloy for longer fretting fatigue life' Measurement vol. 49 pp. 256–265

[10] E. Daniel Kirby and Joseph C. Chen (2007) 'Development of a fuzzy-nets-based surface roughness prediction system in turning operations' Computers & Industrial Engineering vol. 53 pp. 30–42

[11] S. Kumanan & C. P. Jesuthanam & R. Ashok Kumar (2008) Development of a fuzzy-nets-based surface roughness prediction system in turning operations Int J Adv Manuf Technol (2008) vol. 35 pp.778–788.