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Influence of Cutting Parameters on Surface Roughness of Red Brass (C23000) in Turning Using Exponential Model

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Abstract: *This paper examines the effect of cutting parameters (cutting speed, feed rate and depth of cut) onto the surface roughness of red brass during turning. Mathematical model was developed by using experimental data gathered from a series of experiments, based on full factorial design. The experiments were performed on red brass using HSS tool. Exponential model based on regression analysis were developed in this study. It was concluded from the study that the feed rate is the most dominant factor affecting the surface roughness followed by depth of cut and cutting speed. The model developed was evaluated for its competence using statistical methods, coefficient of determination (R^2), mean absolute error (MAPE) and mean square error (MSE).*

Keywords: *brass, cutting force, regression, surface roughness, turning*

1. Introduction

Brass and brass alloys are widely used as industrial materials because of their excellent characteristics such as high corrosion resistance, non-magnetism and good machinability e.g. in bushes, ball valves, butterfly valves etc. of hydraulic devices. Surface roughness is an important parameter in evaluating the performance of the hydraulic equipment [1]. It is necessary to achieve a desired surface topography of a mechanical component during the machining operation, as the surface roughness influences significantly its tribological properties during its useful life. Good surface finish improves the wear and friction characteristics and also increases the fatigue life of a component. In order to predict surface roughness of a mechanical component it is essential to develop an appropriate mathematical model. Surface finish in turning has been found to be influenced in varying amounts by a number of factors such as feed rate, work material, characteristics, work hardness, unstable build up edges, cutting speed, depth of cut, cutting time, tool nose radius and cutting tool edge angles, stability of machine tool and workpiece-setup, chatter and use of cutting fluid [2]. Surface roughness is mostly based on cutting parameters (cutting speed, feed, and depth of cut) and sometimes some other parameters [3]. The various models for optimum surface roughness have been reported in the literature. These models are based on: multi regression technique, physics of the process, fuzzy set based technique, Neural network modeling (NNM) [4]. [5] used multiple regression to predict the surface roughness during hard turning of AISI 4340 steel. [6] investigated the effect of cutting parameters (cutting speed, feed rate and cutting time) on surface roughness and flank wear during the turning of AISI H11, using response surface methodology (RSM). [7] studied the performance and wear behavior of different cubic born nitride tools in finish turning of AISI 52100 steel. [8] developed ANN models to study the effect of cutting conditions on the surface roughness in turning of free machining steel. This necessitates a cutting process optimization to determine the optimal values of the cutting parameters, such as cutting speed, feed rate and depth of cut to fully evaluate the performance and life of the cutting tool. The literature survey reveals that lot of work has been done to model the surface roughness in turning operation using linear regression models, power law models, ANN etc. Conventionally ANOVA has been used to determine the influence of the cutting parameters on the surface roughness. The present paper intends to develop a model based on exponential law and demonstrates how the influence of the cutting parameters can be found without using ANOVA.

2. Experimentation and the exponential model

In this study, cylindrical red brass bars of diameter 30mm and 150mm length as work piece material and HSS tool were used. The experiments were performed on ***Kiloshkar Enterprise 1550*** make lathe under dry conditions. A total of 27 (3^3) experiments were conducted on the basis of full factorial design methodology. The parameter chosen for the study were feed rate, cutting speed and depth of cut. The surface roughness was measured by ***Hommel Etamic WS*** roughness meter. The details of the data obtained from the experiments for red brass are given in Table. 1.

TABLE 1: Experimental data for model construction

Feed rate(mm/rev)	*Depth of cut(mm)*								
	v=840 (mm/min)			*v=1000 (mm/min)*			*v=1280 (mm/min)*		
	0.10	**0.13**	**0.16**	**0.10**	**0.13**	**0.16**	**0.10**	**0.13**	**0.16**
0.40	2.610	2.906	3.126	2.396	2.646	3.271	3.076	3.318	3.566
0.80	2.569	2.532	2.542	2.426	2.626	2.919	2.666	2.854	3.081
0.12	2.896	3.064	3.093	2.856	3.105	3.573	3.296	3.210	4.109

The model of predicted surface roughness, R_a can be expressed as Eq. 1

$$R_a = k \prod_{i=1}^{n} p_i{}^{c_i} \tag{1}$$

where $p_{i,}$ and c_i $i = 1,2,3 \dots n$ are the model parameters and cutting parameters respectively.

Eq. (1) can written as

$$R_a = kp_1{}^{c_1}p_2{}^{c_2}p_3{}^{c_3} \dots \dots .. p_n{}^{c_n} \tag{2}$$

The parameters considered in the present study were cutting speed (*v*), feed rate (*f*) and depth of cut (*d*). Thus Eq. (2) can be written as

$$R_a = k\, p_1{}^{v}p_2{}^{f}p_3{}^{d} \tag{3}$$

using logarithmic transformation, Eq.(3) can be written as Eq. (4).

$$\ln R_a = \ln k + v\ln p_1 + f\ln p_2 + d\ln p_3 \tag{4}$$

$$Y_r = a_o + a_1 v + a_2 f + a_3 d \tag{5}$$

The model parameters in Eq. (5) were obtained by least square method ($\mathbf{c} = (\mathbf{X^T X})^{-1}\mathbf{X^T Y}$). Accordingly Eq.(6) was obtained.

$$R_a = 1.7739 \times\ 1.0003^{v} \times 10.8528^{f} \times 0.764^{d} \tag{6}$$

3. Results and discussion

The experimental and predicted surface roughness is shown in Fig.(1). It is clear from the Fig(1) that the predicted and experimental values of surface roughness are very close to each other. The accuracy of the proposed model was assessed by the statistical methods using coefficient of regression (R^2) mean square error (MSE) and mean absolute error (MAPE) as tabulated in Table 1.

TABLE 2: Statistical parameters of proposed model

R^2	MSE	MAPE
99.84%	0.4035	3.2254%

It is clear from the Table. 1 that the proposed model has very high coefficient of determination R^2, very small mean square error and mean absolute percentage error . These parameters of the model are indicative of the fact that the model is capable to predict the surface roughness with high accuracy. In order to find the influence of each machining parameter on surface roughness Eq. (6) was used to evaluate

$$\left(\frac{\partial R_a}{\partial f}\right)_{d,v}, \quad \left(\frac{\partial R_a}{\partial d}\right)_{f,v} \, and \, \left(\frac{\partial R_a}{\partial v}\right)_{d,f}$$

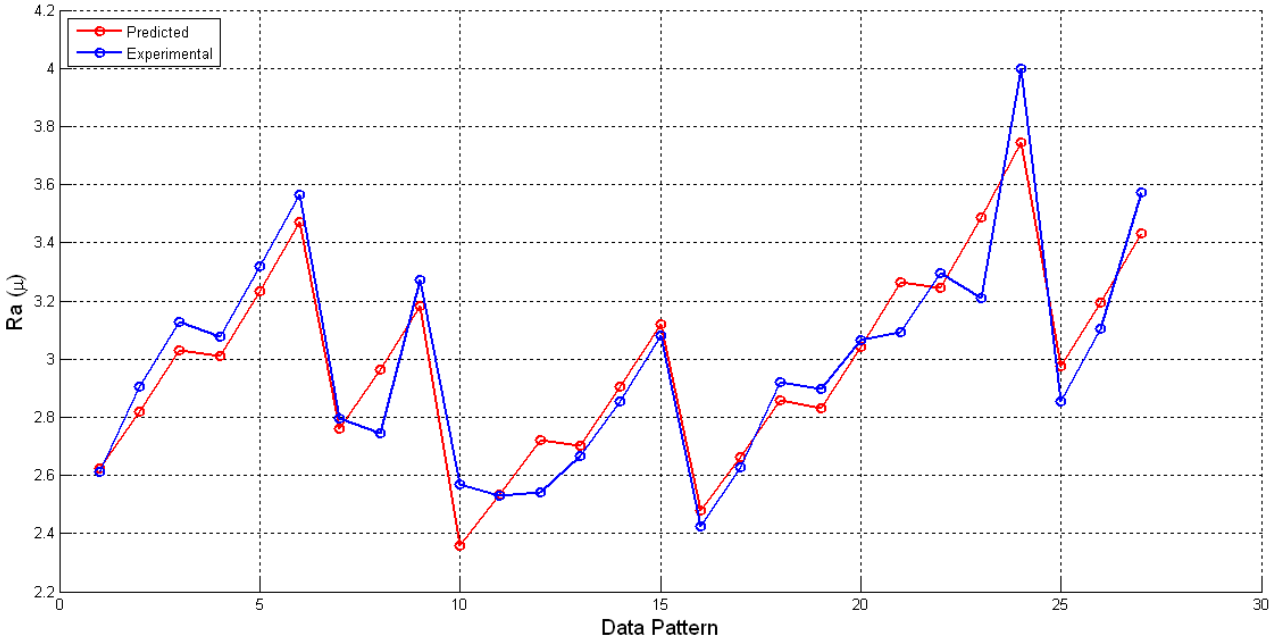

Fig.1. Predicted and experimental values of surface roughness

It was found that

$$\left|\left(\frac{\partial R_a}{\partial f}\right)_{d,v}\right| > \left|\left(\frac{\partial R_a}{\partial d}\right)_{f,v}\right| > \left|\left(\frac{\partial R_a}{\partial v}\right)_{d,f}\right| \quad (7)$$

It was concluded from Eq. (7) that the most dominant factor that influences surface roughness, R_a is feed rate, *f* followed by depth of cut, *d* and least by .cutting speed, *v.* Also

$$\left(\frac{\partial R_a}{\partial f}\right)_{d,v} > 0, \qquad \left(\frac{\partial R_a}{\partial d}\right)_{f,v} < 0 \qquad and \left(\frac{\partial R_a}{\partial v}\right)_{d,f} > 0$$

The above inequalities indicate that the surface roughness increases with increase in feed rate and cutting speed and decreases with increase in depth of cut.

4. Conclusions

The present investigation focused on surface roughness prediction and analysis during turning of red brass using HSS tool. This analysis was carried out by developing surface roughness model of *Ra* using exponential function with feed rate, speed and depth of cut as process parameters. The model developed has only four unknown model parameters. The existence of highly non-linear relationship between the surface roughness and process parameters justifies the use of exponential function. On the basis of R^2, MAPE and MSE it was concluded that the model is in good agreement with the experimental data. It was also concluded from the analysis that the surface roughness is highly sensitive to the feed rate.

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