Optimization Of Surface Roughness Parameters Through Regression Model Analysis

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Abstract— **In the present study an attempt has been made to investigate the influence of cutting parameters on surface roughness of a cast iron specimen undergoing turning operation. Experiments have been performed using Taguchi's orthogonal array. HSS tool is used for cutting operation. Most influencing parameters cutting speed, feed rate and depth of cut are considered for the purpose. Optimization of the cutting parameters has been achieved by analysis of the system through a regression model. A combination of parameters is arrived at for optimum surface roughness. Experimental results also indicate that cutting speed have the largest effect on surface roughness followed by feed rate and depth of cut.**

Keywords— Optimization, surface roughness, Taguchi's method, cutting speed, feed rate, depth of cut, regression model

I. INTRODUCTION

In the present technical era of high productivity quality of the machined parts (in terms of work piece dimensional accuracy, good surface finish, less tool wear on the cutting tools, high metal removal rate and economy of machining in terms of time per component, cost per component and the performance of the product) is one of the prime challenges of metal cutting industry. The quality of design can be improved by improving the quality and productivity in companywide activities. Those activities concerned with quality include quality of product planning, product design and process design. Usually wear test, power consumption, material removal rate and surface finish are the most desirable tests for quality measurement of machining process. Especially surface finish plays an important role on the product quality and it is a parameter of great importance in the evaluation of machining accuracy. In addition to surface finish quality, the tool wear and material removal rate are also importance characteristics in machining operation. In turning good surface finish, high material removal rate and low tool wear are desirable. Also dry turning is becoming important due to awareness towards the environment and worker's health. In addition to environment inputs, the cost associated with cutting fluid is approximately 7-17% of total manufacturing cost which is very high. The machining parameters such as cutting speed, feed and depth of cut, features of tool, work piece material and coolant conditions will highly affect these performance characteristics. Some studies are concerned with the effect of cutting conditions, the influence of work piece hardness, the tool geometry, cutting time, cutting tool materials and the effects of cutting fluid. It is necessary to select most appropriate machining settings in order to improve cutting efficiency, process at low cost and produce high quality products. Here spindle speed, feed rate and depth of cut are considered as the prime factors affecting the surface roughness.

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II. EXPERIMENTAL DETAILS

2.1 Design Of Experiment

To obtain the effect of the cutting parameters on surface roughness in the turning operation for cast iron metal work piece larger number of experiments could be done. But for three levels of working range and three control parameters Taguchi's Orthogonal array asks for nine sets of parameter combinations (L9). Levels of parameters are shown in table 1 and table 2 gives Taguchi's L9 orthogonal array.

Table 1: Levels of control parameters

Control Parameters	Symbols	Levels		
		Low (1)	Medium (2)	High (3)
Spindle speed (rpm)	v	225	382	546
Feed rate (mm/rev)	f	0.4	0.5	0.6
Depth of cut (mm)	d	0.1	0.2	0.3

Table 2: Taguchi's L9 Orthogonal Array

Sl. No.	Factorial Combination		
	v	f	d
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	1
6	2	3	3
7	3	1	3
8	3	2	1
9	3	3	2

2.2 Workpiece Material And Cutting Inserts

In this experiment turning operation is performed on cast iron bars of diameter 16mm and length 40mm. 9 specimens of same dimension are taken and experiment is done for factorial combinations in accordance with Taguchi's L9 Orthogonal array. HSS cutting insert is used to perform the cutting operation.

2.3 Experimental Procedure

Turning operations have been performed on 9 specimens with the given combinations. Roughness measurement is done using a portable stylus-type profilometer, Talysurf (Taylor Hobson, Surtronic 3+, UK). Roughness measurements, in the transverse direction, on the work pieces have been repeated four times and average of four measurements of surface roughness parameter values are recorded. The measured profile have been digitized and processed through the dedicated advanced surface finish analysis software Talyprofile for evaluation of the roughness parameters.

2.4 Development Of Regression Model

Regression model is a statistical method useful for modeling and analyzing engineering problems. The design procedure through Regression model is as follows:
(i) Designing of a series of experiments for adequate and reliable measurement of the response of interest.
(ii) Developing a mathematical model of the second order response surface with the best fittings.
(iii) Finding the optimal set of experimental parameters that produce a maximum or minimum value of response.

III. RESULTS AND DISCUSSION

3.1 Experimental Results

Table 3: Experimental Data

Exp. No.	Control parameter						Surface Roughness (µm)
	Combination of control parameters			Actual value			
				Spindle speed (rpm)	Feed rate (mm/rev)	Depth of cut (mm)	
1	1	1	1	225	0.4	0.1	8.82
2	1	2	2	225	0.5	0.2	9.08
3	1	3	3	225	0.6	0.3	10.9
4	2	1	2	382	0.4	0.2	12.8
5	2	2	3	382	0.5	0.3	9.36
6	2	3	1	382	0.6	0.1	12.74
7	3	1	3	546	0.4	0.3	7.6
8	3	2	1	546	0.5	0.1	6.16
9	3	3	2	546	0.6	0.2	6.46

3.2 Mathematical Modelling

Regression model is used to establish the mathematical relationship between the response (Y) and the various control parameters. The general second order polynomial response surface mathematical model, which analyses the parametric influences on the various response criteria, can be described as follows:

$$Y=b_0+\sum_{i=1}^{k} b_i x_i+\sum_{i=1}^{k} b_{ii} x_i^2+\sum_{i\neq j}^{k} b_{ij} x_i x_j \text{ .... (1)}$$

Where Y is response and (1, 2, …, k) are coded levels of k quantitative variables. The coefficient is the constant term; the coefficients are for the linear, quadratic, and interaction terms. After putting actual values from the experiments 9 equations are formed. The 10th equation is found by adding the corresponding coefficients of different parameters.

$$Y=b_0+b_1 v+b_2 f+b_3 d+b_4 v^2+b_5 f^2+b_6 d^2+b_7 vf+b_8 vd+b_9 fd \text{ ....(2)}$$

Here x_1, x_2 and x_3 represent v, f and d in equation (1)

These equations are solved in *Matlab* and the coefficients are found to be:

$b_0=16.4922$ $b_1=-138.706$ $b_2=0.1453$ $b_3=36.1135$ $b_{11}=-0.001$
$b_{22}=177.2741$ $b_{33}=-99.2741$ $b_{12}=-0.0987$ $b_{13}=-0.0105$ $b_{23}=-2.27\text{x}10^{-13}$

Hence the final regression equation becomes

$$Y=16.4922+0.1453v-138.7068f+36.1135d-0.0001v^2+177.274f^2-99.2741d^2-0.0987vf-0.0105vd-2.27\times 10^{-13}fd \text{.........(3)}$$

3.3 Interpretation Of Results

Effects of individual parameters on the surface roughness are found by varying one parameter at a time and fixing other two parameters at numerical values which are at the middle of the working ranges. Fig.1 shows the changes of surface roughness with variations in spindle speed within its range. The feed rate and depth of cut are kept fixed at values 0.5 mm/rev and 0.2 mm respectively. Fig.2 represents the variation of surface roughness when feed rate is varied in its range. Spindle speed and depth of cut are kept fixed at 382 r.p.m. and 0.2 mm respectively. Fig.3 shows how surface roughness changes due to variations in depth of cut. Depth of cut is varied from 0.1mm to 0.3 mm and feed rate and spindle speed are kept constant at 0.5 mm/rev and 382 r.p.m respectively.

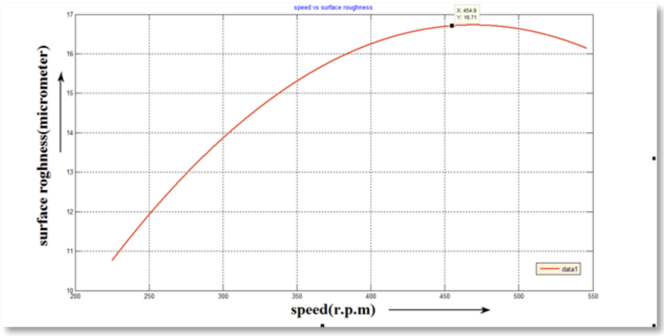

Fig.1: Surface roughness vs Spindle speed

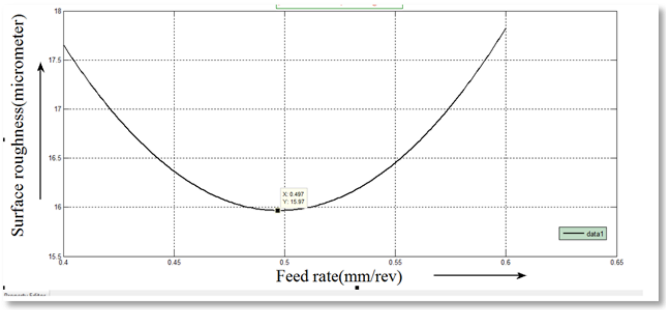

Fig.2: Surface roughness vs Feed rate

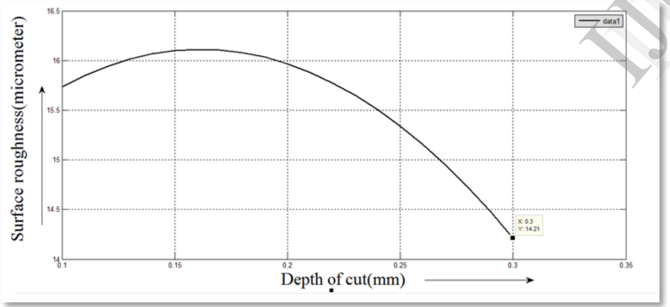

Fig.3: Surface roughness vs Depth of cut

From fig.1 it can be seen that surface roughness is best at the spindle speed 225 r.p.m. Fig.2 shows that feed rate 0.497 mm/rev gives best surface roughness and Fig no. 3 indicates that at 0.3 mm depth of cut surface roughness is best.

Hence the best combination of control parameters for optimum surface roughness within the considered parameter ranges is

v = 225 r.p.m,
f = 0.497 mm/rev and
d = 0.3 mm

The corresponding surface roughness is 7.14 μm.

IV. CONCLUSION

Hence, from the experimental study it can be concluded that it is possible to find a set of control parameters within their working ranges which will provide optimum surface roughness of a specimen undergoing turning operation. Therefore, with the knowledge of optimum set of parameters, it will be possible to produce good quality products when operating ranges are known.

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