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Modeling Of Metal Cutting Process Using Response Surface Methodology

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Abstract
The goal of modern industry is to manufacture low cost, high quality products in short time. Optimum machining parameters are of great concern in manufacturing environments, where economy of machining operation plays a key role in competitiveness in the market. A number of researchers have dealt with the optimization of machining parameters, considering only turning operations and graphical methods to determine the optimum speed, feed and depth of cut. In this work, work pieces machined by Computer Numerical Control machine centre are evaluated according to Response Surface Methodology with an objective function of obtaining good surface finish using single tool operations. Optimum machining parameters resulting from this work are intended for use by Numerical Control machines in order to improve machining efficiencies, improve quality, and reduce rework and scrap.

Keywords*: Statistical Modeling, Metal cutting, cutting parameters*

INTRODUCTION

Metal cutting is one of the most significant manufacturing processes in material removal. Selection of cutting parameters is an important task to for achieving high cutting performance in a turning operation, it. Measuring surface roughness is a crucial concern for an immense range of industries and applications, from auto component wear to medical implant efficacy, from micro-electro-mechanical systems inspection to semiconductor thin-film uniformity. Many of the major advances in science and industry over the past half century would not have been possible without accurate surface roughness metrology Usually, the desired cutting parameters are determined based on experience, tables or by use of a handbook [1-3] . However, this does not ensure that the selected cutting parameters have optimal or near optimal cutting performance for a particular machine and environment. To select the cutting parameters properly, several mathematical fashions [4–9] primarily based on statistical regression techniques or neural computing had been constructed to establish the relationship between the slicing overall performance and the slicing parameters. a few other researchers have tried to locate the affects of diverse machining parameters inclusive of reducing speed, feed charge, rake perspective and tool geometry on burrs [10-12] Taguchi method [13,14]is used to determine the desired cutting parameters more efficiency. Response Surface Methodology (RSM) [15, 16] is used to find a set of process variables that produce the desired surface roughness in metal cutting process.

DEVELOPED METHODOLOGY

Following steps are employed to establish the effect of process parameters on surface roughness in machining process are

1. Identification of cutting parameters
2. Design Matrix using Response surface Methodology
3. Conducting the experiments
4. Developing the mathematical model
5. Conducting the confirmatory tests

Identification of cutting parameters.

The major parameters which affect the machining operations are identified as spindle speed, depth of cut, fees rate, tool nose radius and material properties [20]. The material properties of the work piece used, AA 6351 Aluminum Alloy is given below in Table 1.

***Table 1** Material Properties of used AA 6351 Aluminum Alloy*

Properties	Values
Density	2.6-2.8 ×1000 kg/m^3
Poisson's Ratio	0.33
Elastic Modulus	70-80 GPa
Tensile Strength	250 Mpa
Yield Strength	150 Mpa
Elongation	20 %
Hardness	95 HB500
Shear Strength	200 Mpa
Fatigue Strength	90 Mpa

Experimental Design using Response surface Methodology

In statistics, response surface methodology explores the relationships between several explanatory variables and one or more response variables. The method was introduced by G. E. P. Box and K. B. Wilson in 1951. The main idea of RSM is to use a sequence of designed experiments to obtain an optimal response. The response surface methodology became composed of an experimental layout to discover an approximate model between composite design to attain a second-order regression version and the experimental factors. desk 2 indicates the crucial composite layout employed in this paintings for 4 elements and 3 ranges.

Conducting the experiments

Thirty experiments were performed under cutting environment. For each experimental trial, a new cutting edge was used. Each trial was repeated twice taking into consideration the cost of inserts, machining, cryogenic cutting environment and high repeatability of CNC machines. Cutting conditions were selected based on some preliminary investigations and industrial survey. The responses investigated were the surface roughness. Experiment was done using an EXPERT didactic PC lathe an advanced unit of a PC programmable lathe and possesses a range of accessories that makes it usable as a PC-driven lathe, aimed at didactic use and an exclusive property of ALECOP. AA 6351, Aluminum alloy bars (24mm diameter and 60mm length) were used for the experimentation. The average temperature of the environment was maintained at 25 ±3 °C during machining. A portable high-performance surface roughness and waviness measuring instrument, characterized by skid less measurement SE1200 was used to measure the Ra value of surface roughness in microns and the responses were recorded. Experimental set up for conducting experiments are shown in Figure 1. The ranges of parameters were spindle speed (X1) from 800 to 1200 rpm, feed rate (X2) 40 to 60 mm/min, depth of cut (X3) from

0.30 to 0 .6 mm and tool nose radius (X4) from 0.4 to 0.8 mm.

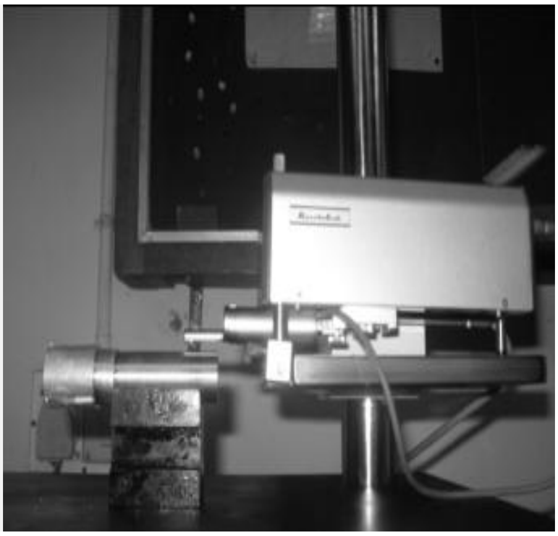

Fig.1. *Experimental set up*

Developing the mathematical model

Mathematical models are useful for selecting correct process parameters to achieve the desired surface finish. In order to predict the surface roughness using the experimental data, the statistical method of Multiple Regression Analysis is used. Surface roughness (X5), micron = 1.5966 - (0.005X1) + (.0016 X2) - (.2263) – (0.1234 X4). From the above equation, new values of surface roughness are predicted.

Table 2 *Design matrix for central composite design*

Trial Numbers	Coded units				Response
	X1	X2	X3	X4	X5
1	-1	-1	-1	-1	1.013
2	+1	-1	-1	-1	1.008
3	-1	1	-1	-1	1.169
4	+1	1	-1	-1	1.148
5	-1	-1	+1	-1	1.079
6	+1	-1	+1	-1	1.013
7	-1	1	+1	-1	1.157
8	+1	1	+1	-1	0.827
9	-1	-1	-1	+1	1.002
10	+1	-1	-1	+1	0.95
11	-1	1	-1	+1	1.174
12	+1	1	-1	+1	1.024
13	-1	-1	+1	+1	1.229
14	+1	-1	+1	+1	0.744
15	-1	1	+1	+1	1.081
16	+1	1	+1	+1	0.815
17	-1	0	0	0	1.229
18	+1	0	0	0	0.952

19	0	-1	0	0	1.131
20	0	1	0	0	1.084
21	0	0	-1	0	1.166
22	0	0	+1	0	1.298
23	0	0	0	-1	0.967
24	0	0	0	+1	1.008
25	0	0	0	0	1.196
26	0	0	0	0	1.156
27	0	0	0	0	1.156
28	0	0	0	0	0.977
29	0	0	0	0	1.048
30	0	0	0	0	1.055

Conducting the confirmatory Tests

To determine the accuracy of the developed models developed, confirmatory runs are conducted with the same experimental set up. In the confirmatory tests, the process variables are assigned some intermediate values and responses are measured. Input values and results from the confirmatory experiments are given in Table 3. The results show that the accuracy of the model is above 95%.The percentage of error is calculated by [{Actual
value- predicted value}/predicted value] x 100

Table 3 *Comparison of results*

spindle speed	feed rate	depth of cut	tool nose radius	Experimental values	Predicted values	% error
850	44	0.36	0.4	1.013	1.111	- 9.13
950	48	0.42	0.6	1.135	1.029	9.34
1050	52	0.48	0.8	0.851	0.947	-11.28
1150	56	0.54	0.6	1.041	0.915	12.10

CONCLUSIONS

The plan of investigation and analysis of cutting parameters is elaborated. Significant process parameters affecting the cutting process are identified as spindle speed, feed rate, depth of cut and tool nose radius. Indicators to predict the machining quality are identified in terms of surface roughness Experiments were conducted using Central composite design orthogonal array and the responses are recorded. The performance characteristics of the cutting parameters are evaluated using regression analysis. Mathematical models are developed from the responses obtained and are validated. This work can be extended to other manufacturing process also.

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