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Optimization of Process Parameters of Tool Wear in Turning Operation

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ABSTRACT
Tool Wear is of great apprehension in machining industries since itaffects the surface quality, dimensional accuracy and production cost of the materials / components. In the present study twenty seven experiments were conducted as per 3 parameter 3 level full factorial design for turning operation of a mild steel specimen with high speed steel (HSS) cutting tool. An experimental investigation on cutting tool wear and a mathematical model for tool wear estimation is reported in this paper where the model was simulated by computer programming and it has been found that this model is capable of estimating the wear rate of cutting tool and it provides an optimum set of process parameters for minimum tool wear.
Keywords: Tool Wear, Spindle speed, Depth of Cut, Feed Rate, DOE etc.

I. INTRODUCTION

Machining operations have been the core of the manufacturing industry since the industrial revolution.Increasing the productivity and the quality of the machined parts are the main challenges of metal-based industry.There has been increased interest in monitoring all aspects of the machining process. Turning is the one most widely used among all the cutting processes.The most important machining parameters (cutting speed, feed rate, depth of cut) accelerate tool wear which in turn affects the surface finishing. The tool wear is directly related to the machining parameters. Here regression analysis have been used to find out the best combination of process parameters for minimum tool wear in turning operations in order to improve quality of machined products.

II. EXPERIMENT

The experiments were performed following full factorial design of experiments. Design of experiments is an effective approach to optimize the parameters in various manufacturing related process, and one of the best tool for analyzing the effect of process parameters over some specific ranges. The selection of such points in design space is commonly called design of experiments (DOE). In this work related to turning of Mild steel, the experiments were conducted by considering three main influencing process parameters such as spindle speed, Feed Rate and Depth of Cut at three different levels namely Low, Medium and High. So according to the selected parameters a three level full factorial design of experiments ($3^3 = 27$) were designed and experiments were conducted according to those combinations. The level designation of various process parameters are shown in table 1.

Table 1.Limits and levels of control parameters

Control Parameters	Limits		
	Low(1)	**Medium(2)**	**High(3)**
Spindle Speed (V) rpm	250	590	930
Feed Rate (f) mm/rev	0.16	0.40	0.64
Depth of cut (d) mm	0.6	0.8	1.0

Table 2. Experimental Data

Exp. No.	**Spindle Speed (v) rpm**	**Feed Rate (f) mm/rev**	**Depth of Cut (d) mm**	**Response (T = Tool Wear) mm**
1.	250	0.16	0.6	0.03
2.	250	0.16	0.8	0.06
3.	250	0.16	1.0	0.08
4.	250	0.40	0.6	0.05
5.	250	0.40	0.8	0.07
6.	250	0.40	1.0	0.09
7.	250	0.64	0.6	0.07
8.	250	0.64	0.8	0.08
9.	250	0.64	1.0	0.10
10.	590	0.16	0.6	0.04
11.	590	0.16	0.8	0.06
12.	590	0.16	1.0	0.08
13.	590	0.40	0.6	0. 06
14.	590	0.40	0.8	0.08
15.	590	0.40	1.0	0.10
16.	590	0.64	0.6	0.08
17.	590	0.64	0.8	0.09
18.	590	0.64	1.0	0.11
19.	930	0.16	0.6	0.05
20.	930	0.16	0.8	0.08
21.	930	0.16	1.0	0.10
22.	930	0.40	0.6	0.07
23.	930	0.40	0.8	0.09
24.	930	0.40	1.0	0.12
25.	930	0.64	0.6	0.09
26.	930	0.64	0.8	0.11
27.	930	0.64	1.0	0.16

III. MATHEMATICAL MODEL DEVELOPMENT

The general second order polynomial mathematical model, which analyses the parametric influences on the various response criteria, can be described as follows:

Tool Wear, $T = B_0+\sum_{i=1}^{k} B_iX_i+\sum_{i=1}^{k} B_{ii}X_i^2+ \sum_{i,j=1, i\neq j}^{k} B_{ij}X_iX_j$ …………………….. (1)

Where T is Response and X_i(i, j =1, 2, ... , k) are levels of k quantitative variables. The coefficient B_0 is the constant term; the coefficients B_i,B_{ij}, $B_{ij}$are for the Linear, Quadratic and Interaction terms. After putting actual values from the experiments, 27 equations are formed.

The general equation for this experiment,

$\mathbf{T=B_0+B_1v+B_2f+B_3\, d+ B_{11}\, v^{2}+B_{22}f^{2}+B_{33}d^{2}+ B_{12}vf+ B_{13}vd+ B_{23}fd}$ …………………...(2)

Here X_1=**v,** X_2=**f,**X_3=**d**

Theequations formed by using the experimental data are solved by using Least Square Method in **Matlab software** and the coefficients are found to be:

B_0=-0.0233,	B_1= -0.0001,	B_{11}= 0.0000,	B_{12}= 0.0001,
	B_2 =-0.0449,	B_{22}= 0.0133,	B_{13}=0.0001,
	B_3=-0.0030,	B_{33}= 0.0530,	B_{23}= -0.0174

So the final equation found by regression analysis is as follows:

$\mathbf{T=-0.0233 - 0.0001v + 0.0449\, f - 0.0030d+0.0000v^2 + 0.0133\, f^2 + 0.0530\, d^2+ 0.0001\, vf + 0.0001vd- 0.0174\, fd}$

IV. RESULTS AND DISCUSSION

The nonlinear 2nd order regression equation representing the mathematical model for tool wear is simulated in computer to determine the effects of individual process parameters on tool wear which is done by varying one parameter at a time within its range and keeping the other two parameters at their mean value.

Figure 4.1 shows the variation of tool wear with the change of spindle speed. Spindle speed is made to vary from 250 RPM to 930 RPM and Feed Rate & Depth of Cut are kept constant at mean values within their ranges, which are 0.4 mm/rev & 0.8 mm respectively.

Figure 4.1 shows that the tool wear increases with increase of Spindle Speed. It has been found from the graph that tool wear is minimum at spindle speed of 250 RPM.

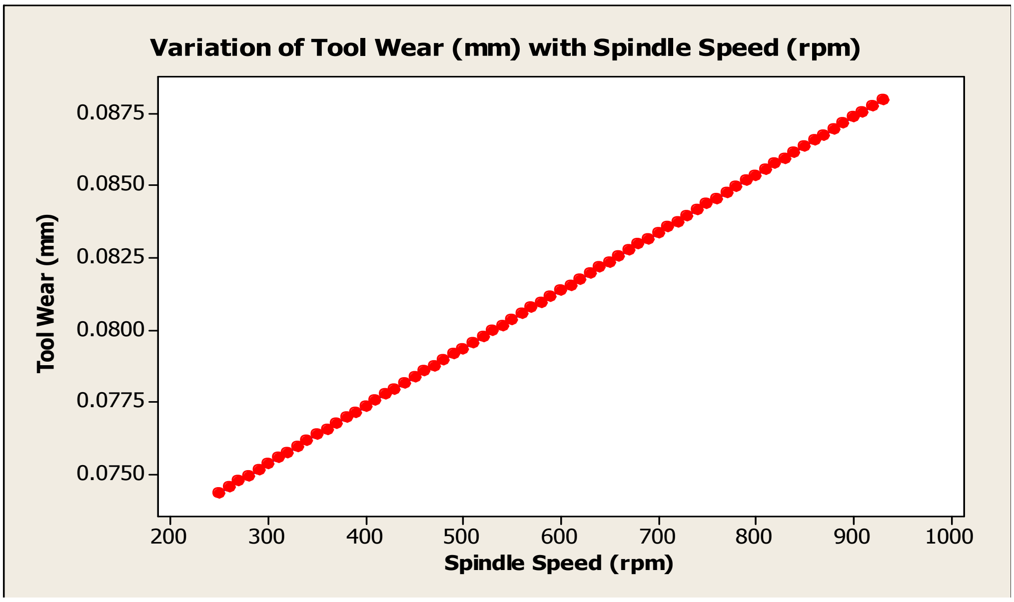

Figure 4.1 Tool Wear (mm) vs Spindle Speed (rpm)

Figure 4.2 shows the variation of tool wear with the change of Feed Rate. Feed Rate is made to vary from 0.16 mm/rev to 0.64 mm/rev and Spindle Speed & Depth of Cut are kept constant at mid values within their ranges, which are 590 RPM & 0.8 mm respectively.

Figure 4.2 shows that tool wear increases with increase of Feed Rate. It is has been found from the graph that tool wear is minimum at Feed Rate of 0.16 mm/rev.

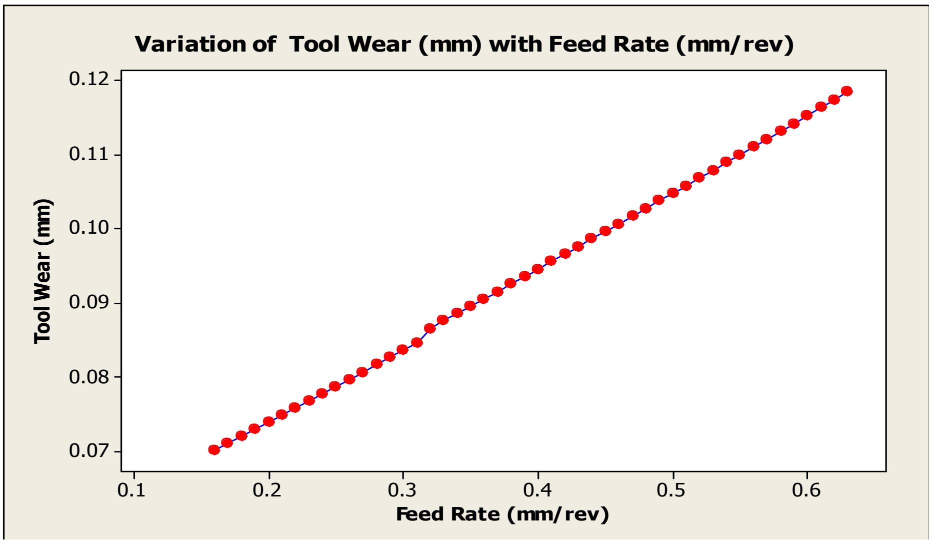

Figure 4.2 Tool Wear (mm) vs Feed Rate (mm/rev)

Figure 4.3 shows the variation of tool wear with the change of Depth of Cut. Depth of Cut is made to vary from 0.6 mm to 1.0 mm and Spindle Speed & Feed Rate is kept constant at mid values within their ranges, which are 590 RPM & 0.40 mm/rev respectively.

Figure 4.3 shows that tool wear increases with increase of Depth of Cut. It is has been found from the graph that tool wear is minimum at Depth of Cut of 0.6 mm.

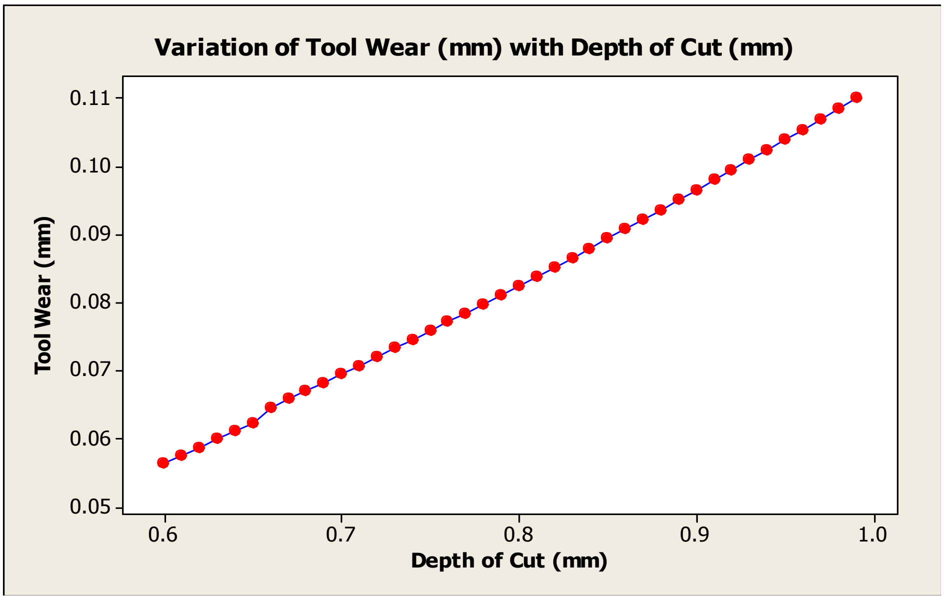

Figure 4.3 Tool Wear (mm) vs Depth of Cut (mm)

V. CONCLUSION

Analysis of the variation of Tool Wear against individual process parameters shows that Tool Wear of the specimen will be best at three distinct values of the process parameters. Hence the optimum set of process parameters found from the computer simulation and the graph for minimum tool wear within considered ranges are:

Spindle Speed = 250 RPM
Feed Rat = 0.16 mm/rev
Depth of Cut = 0.6 mm

Hence it is possible to limit the tool wear while machining by choosing the optimum set of process parameters.

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