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Response Surface Methodology Based Optimization of Dry Turning Process

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Abstract

Dry machining is now a days used in many manufacturing organizationsbecause of health hazards identified by the use of coolants while machining. If properly controlled and designed dry machining can be beneficial in many aspects of machining. In current investigation optimization and modeling of dry turning parameters of EN-8 steel for surface finish requirements are proposed. EN-8 steel is generally used for general-purpose axles, shafts, gears, bolts and studs. During the investigation response surface methodology is used for modeling of surface finsh 'Ra' parameter.RSM based response optimizer is used to optimize the cutting parameters while turning operation. The predicted RSM model shows a good agreement with experimental results. Hence these models can be used to predict the surface roughness within the range of cutting parameters under investigation. Cutting speed of, feed of and depth of cut of are the optimized parameters found during the investigation.

Keyword: Dry machining; Turning; Response Surface Methodology; Optimization; EN-8 steel

Introduction: -Dry machining is a technology in which machining operations are carried out without the use of coolant. Recently due to the unfavorable effects of coolants used during the machining on human health trend is moving towards minimizing the use of coolants. Sometimes if conditions are favorable coolants may be completely avoided during the machining operations.Long term exposure of lubricants and coolants can lead to many health hazards and health professional around the world has pointed out these facts [1]. Recently lot of concern is given to coolant costs and environmental problems from large quantity cutting fluid applications therefore dry and near dry cutting conditions are more popular developments in machining now a day's [2]. The latest developments in manufacturing and cutting technology can allow machining of many metal alloys with very less or without use of coolant.

The characterization machined surface texture is still a challenging metrological problem when high precisionand functional performance requirements exist [3].While optimization of optimization of cutting parameters to minimize surface roughness during turning of hardened AISI 4140 steel with coated carbide tools by Asilturk et al. [4] have mentioned that feed rate is the most significant effect on the surface topology parameters Ra and Rz.Dinizand Micaroni [5]reported increase in surface roughness with increases in feed however, for wet cutting this incerement is greater than that for for dry cutting. Surface roughness values in dry machining and machining with coolant for EN-8 steel are very close to each other, therefore if conditions are favorable one can go for dry machining [6].

Selection of optimum cutting parameters during a machining process, which gives best performance, is cumbersome task for supervisors and machine operators on shop floor. They have to deal with this problem during development of every new product's machining. Many techniques has been developed recently to optimize performance of machining processes. Every technique offers some advantages and also come with some limitations.

RSM is a collection of mathematical and statistical techniques, which are very useful during modeling, and analysis ofresponses, which are influenced by several variables and here objective is to optimize the response. RSM also gives relationships between one or more measured responses and the input factors [7,8].Asiltürkand Neseli [9] presented Taguchi method and the RSMbased optimizationfor CNC turning parameters. They found feed is most significant parameter for surface roughness (Ra and Rz) with the percent contribution of 85.5% in bringing down the average roughness values.Aouici et al.[10] presented use of RSM in analysis and optimization of the hard turning of AISI H11 steel with CBN7020 tool .They concluded that RSMtechnique allows investigating the influence of each one on the cutting process progress outputs such as roughness and force components.

This paper describes use of RSM based desirability function for optimization of dry turning parameters for EN-8 steel. Speed, feed and depth of cut are the main cutting parameters used in this investigation. The optimization of above parameters is carried out for a response variable namely surface roughness. For optimization purpose a response optimizer tool which uses the principle of desirability is used during the investigation.

Experimental Details

In following sections all the details regarding experimentations has been discussed.

Set upDetails

The experimental set up is shown in Fig. 1.Total twenty seven experiments are carried out during this investigation. For every run fresh corner of insert is used which is the main requirement for analysis. Table 1 gives details of all the elements used during the experimental work.

Table 1 Details of Experiment

Machine	CNC turning center
Workpiece	EN-8 steel 40mm in length and 40 mm in diameter
Turning Length	30mm
Insert	TNMG 06 04 04 M3
Tool Holder	MTLNR 25 25 M 06 W.
Surface Roughness Measurement	Mitutoyo SJ-210 sampling length of 0.8mm

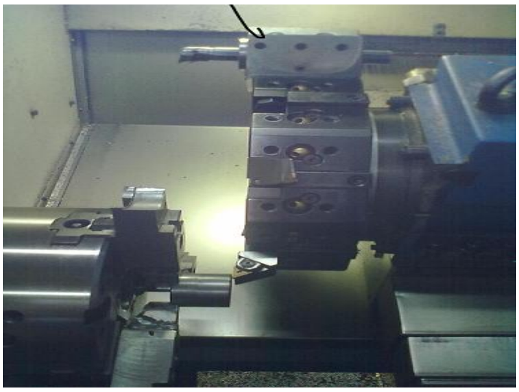

Figure1 Experimental Set Up

Plan of Experiment

Taguchi orthogonal array L_{27} is used for execution of experiments.In turning three main cutting parameters are speed, feed and depth of cut, same parameters are taken during this investigation.Each of above parameter is chosen with three levels. The parameters with their actual levels are shown in Table 2. L_{27} (3^{13}) array has 27 rows corresponding to the number of test (26 degree of freedom) with 13 columns at 3 levels as shown in Table 3. While execution of experimental plan twenty seven experiments are carried out according to Taguchi L_{27} array. After machining all the components are cleaned and surface roughness values are measured with roughness tester. With recorded value of surface roughness the optimization of cutting parameters for surface roughness is done using response surface methodology based desirability function. For this purpose, the response optimizer tool is used with Minitab software**.**Figure 2 indicates plan of optimization.

Table.2 Cutting Parameters and Their levels

Parameters	Level 1	Level 2	Level 3
Speed	125.60	150.72	175.84
Feed	0.2	0.25	0.3
Depth of cut	0.2	0.4	0.6

Table 3 Taguchi L_{27} array

Speed V (m/min)	Feed f (mm/rev.)	DoC d (mm)	Surface Roughness R_a(µm)
125.6	0.2	0.2	4.1527
125.6	0.2	0.4	3.884
125.6	0.2	0.6	4.322
125.6	0.25	0.2	7.0147
125.6	0.25	0.4	5.8123
125.6	0.25	0.6	6.1787
125.6	0.3	0.2	8.5757
125.6	0.3	0.4	8.384
125.6	0.3	0.6	9.3137
150.72	0.2	0.2	3.7507
150.72	0.2	0.4	3.87
150.72	0.2	0.6	4.131
150.72	0.25	0.2	5.7883
150.72	0.25	0.4	6.408
150.72	0.25	0.6	5.7337
150.72	0.3	0.2	8.0542
150.72	0.3	0.4	8.377
150.72	0.3	0.6	8.7917
175.84	0.2	0.2	3.6503
175.84	0.2	0.4	3.8543
175.84	0.2	0.6	3.85
175.84	0.25	0.2	6.015
175.84	0.25	0.4	5.986
175.84	0.25	0.6	5.9207
175.84	0.3	0.2	9.0097
175.84	0.3	0.4	8.811
175.84	0.3	0.6	9.0937

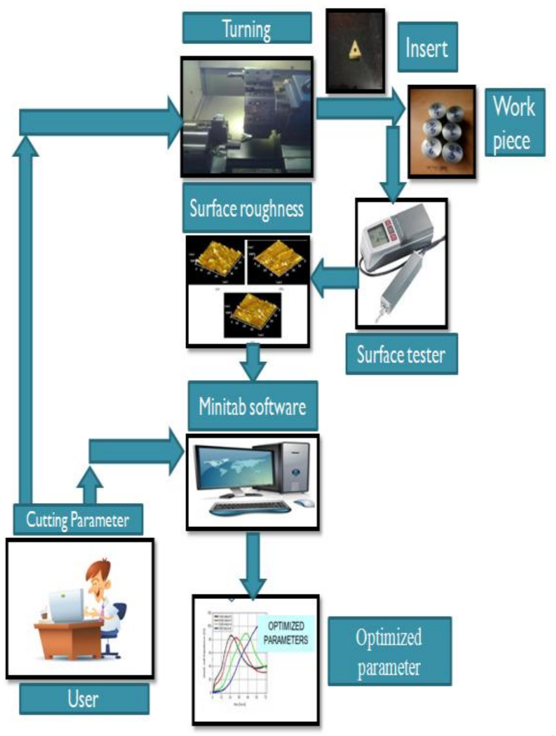

Figure 2 Plan of Optimization

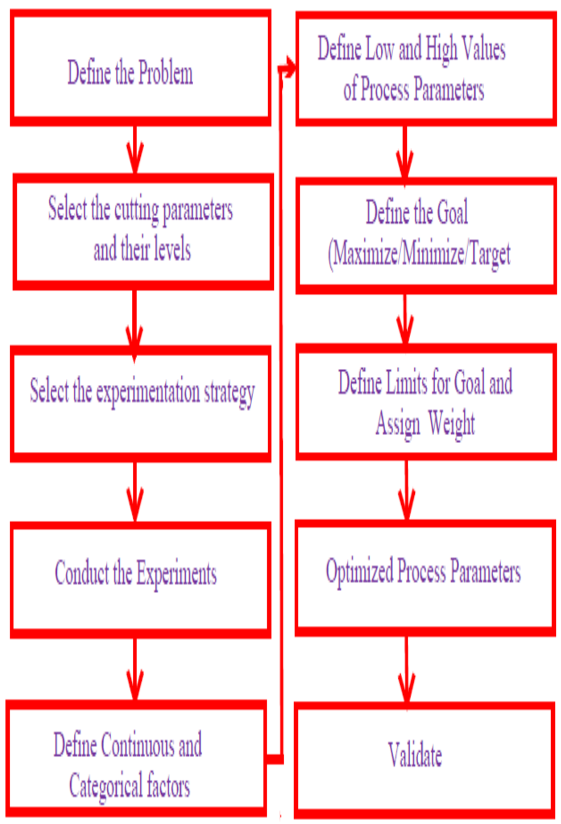

Figure 3 Flow of RSM-Desirability Optimization

Resultand Discussions

In this investigation optimization is carried out by using RSM based desirability function. The main aim of desirability function approach is to transforms estimated response on each quality characteristic (y_i) to a scale-free value d_i, called desirability. Desirability d_i is a value between 0 and 1.This value increases as the desirability of the equivalent response increases [11]. Maximize, minimize or to target a response are the main goals of any optimization process. For these goals a set of optimal processing parameters is derived. The steps involved in optimization with RSM based desirability are as shown in Fig. 3. While optimization weight of desirability function is taken as 0.5.Lower and upper value in the plot indicates the limits for process parameters. The middle value indicates optimized parameters.The goal during this investigation is to minimize the surface roughness. Following parameters and equations are used to optimize the parameters by RSM based desirability function [11, 12].

y_i= Predicted value of i^{th} response

T_i=Target value of i^{th} response

L_i=Lowest acceptable value for i^{th} response

U_i=Highest acceptable value for i^{th} response

d_i=Desirability for ith response

D=Composite desirability

r_i=Weight of desirability function

W_i=Importance of i^{th}response

$W = \Sigma W_i$

The mail goals in desirability approach based optimization are

- Maximize the Response Desirability

$d_i = 0$ if $y_i < L_i$

$d_i = ((y_i - L_i)/(T_i - L_i))^{r_i}$ if $L_i \leq y_i \leq T_i$

$d_i = 1$ if y_i

- Minimize the Response Desirability

$d_i = 0$ if $y_i > U_i$

$d_i = ((U_i - y_i)/(U_i - T_i))^{r_i}$ if $T_i \leq y_i \leq U_i$

$d_i = 1$ if $y_i < T_i$

- Target the Response Desirability

$d_i = ((y_i - Li)/(Ti - Li))^{ri}$ if $Li \leq y_i \leq Ti$

$d_i = ((Ui - y_i)/(Ui - Ti))^{ri}$ if $T_i \leq y_i \leq U_i$

$d_i = 0$ if $y_i < L_i$

$d_i = 0$ if $y_i > U_i$

Composite Desirability: composite desirability can be computed as

$$D = (d_1 \times d_2 \times d_3 \times \ldots\ldots \times d_n)^{1/n}$$

The composite desirability is considered only when the optimization problem is of multiple responses.For any machining process it is desirable to have minimum surface roughness therefore the target to minimize the desirability. Hence, in this investigation the target is selected as minimum roughness value from the Table 3 which is 3.6503µm and maximum limit is set as 9.3137µm which is the largest surface roughness value obtained during the investigation, refer Table 3. The starting points for optimization are set as Speed at 125.6 m/min, Feed at 0.2 mm/rev and Depth of Cut at 0.2 mm.The optimum process parameters for surface roughness are 163.153 m/min speed, 0.2 mm/rev. feed and 0.3939 mm depth of cut. The global solution obtained from response optimizer is shown in Table 4.Figure 4 shows Optimized process.

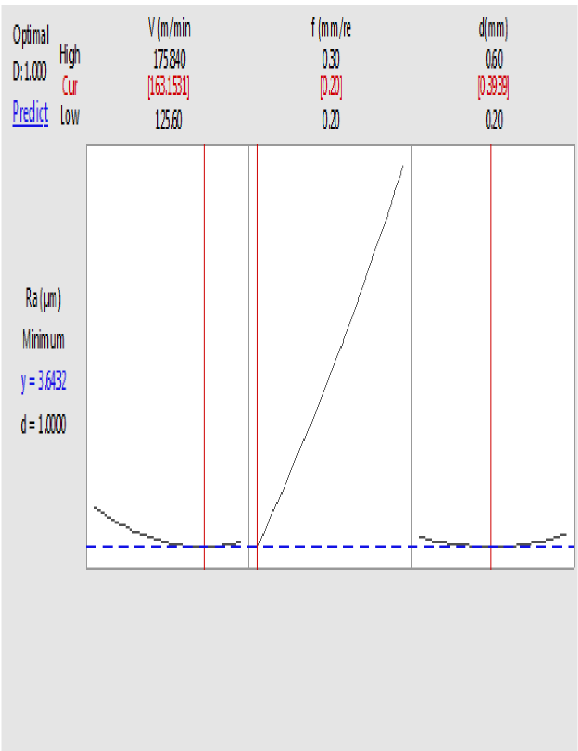

Figure 4 Response Optimizer

Table 4 Global Solution with Optimal Parameter Setting and Result of Validation

Global Solution	Predicted	Validation
Cutting Speed V (m/min)	163.153	163.153
Feed f (mm/rev)	0.2	0.2
Depth of Cut d (mm)	0.3939	0.3939
Surface Roughness Ra	**3.6432**	**3.639**

Conclusions

This paper describes use of RSM based desirability function for optimization of dry turning parameters for EN-8 steel. Speed, feed and depth of cut are the main cutting parameters used in this investigation. The optimization of above parameters is carried out for a response variable namely surface roughness. For optimization purpose a response optimizer tool which uses the principle of desirability is used during the investigation. Based on this work, the following conclusion may be drawn for the cutting condition used.

- The Feed has highest influence on the surface roughness.Surface roughness increases with increase in feed for all levels.
- RSM **-**Desirability function based optimum cutting parameters are Cutting Speed-163.153, Feed0.2 and Depth of Cut-0.3939 mm.At this optimum parameters Predicted surface roughness is 3.6432.A confirmation test at same cutting parameters gives a roughness value of 3.639.This indicates an accuracy of optimization model derived by RSM-Desirability approach.

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