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Optimization of Cutting Parameters for Turning Operation on CNC Lathe

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Abstract

The main objective of today's manufacturing industries is to produce low cost, high quality products in a shortest possible time. The selection of optimal cutting parameters is a very important aspect for every machining process in order to enhance the quality of machining products and reduce the machining costs. This paper investigates the machining of alloy steel to find optimal parameters for CNC turning process. The Full Factorial method is used to formulate the experimental layout, to analyse the effect of each parameter on the machining characteristics and to predict the optimal choice for each turning parameters such as Speed, Feed and Depth of cut. It is found that these parameters have a significant influence on machining characteristics such as Material removal rate (MRR) and Surface roughness (SR). The Analysis of Variance (ANOVA) is used to study the performance characteristics in turning operation.

Keywords: *Full Factorial , Surface roughness, ANOVA, Quality.*

1. Introduction

The global market has been more competitive than ever. Challenge of modern machining industries is mainly focused on achieving high quality, in terms of work piece dimensional accuracy, surface finish, high production rate, less wear on the cutting tools, economy of machining in terms of cost saving and increasing the performance of the product with reduced environmental impact.

Metal cutting plays a pivotal role in innumerable manufacturing processes and is widely used in various engineering industries. Surface roughness is an important parameter of metal cutting as it is the characteristic of quality and influences performance of the mechanical parts and also the production cost. Cost and quality are inversely proportional to each other. Thus we need to find a way to balance both objectives. Thus, selection of proper tool and work-piece combination which influences cost and quality can help us to achieve the best possible solution to our problem.

2. Literature Review

In this study, the effect of different foaming durations on the pore structure of Al foam material was examined and the foaming duration for homogenous pore distribution was determined (Gultekin Uzun et al, 2017). The obtained samples were drilled with drills of different diameters at different feed rates and cutting speeds. Feed forces increased with the increase in cutting speed. Feed force exhibited increases in the interval 200–500 % with the increase in feed amount. Foamed structure affected the chip breakings causing an increase in chip adhesions proportionally with the cutting speed.

Bharadwaj et al, 2017 showed optimization of process parameters in drilling EN8 steel using Taguchi technique and gave conclusion that Surface roughness increases with increase in feed, increase in depth of hole while with spindle speed, surface roughness initially decreases as the spindle speed increases from 360 RPM to 490 RPM and surface roughness increases with increase in spindle speed from 490 RPM to 680 RPM and all the three independent parameters (spindle speed, feed and depth of hole) seem to be the influential drilling parameters that affect the surface roughness.

(Kima et al, 2016). In this study, a micro-patterned insert, fabricated using an EDM process was shown to reduce force, coefficients of friction, and tool wear through improved tri-biological properties. The coefficient of friction was calculated by modelling continuous and saw-chip formation.

Sathiyaraj S. et al, 2015, investigated on optimization of machining parameters for EN8 Steel through Taguchi method and conclude that cutting speed has most dominant effect on the observed surface roughness, followed by feed rate and depth of cut, whose influences on surface roughness are smaller.

Süleyman Neseli et al, 2010, have investigated the influence of tool geometry parameters(such as nose radius, approach angle and rake angle) on the surface finish in turning operations of AISI 1040 steel on lathe machine by using Al2O3 coated tool inserts CNMG 120404-BF, CNMG 120408-BF, CNMG 120412-BF based on the response surface methodology. In this study, L27Taguchi standard orthogonal array issued as the experimental design and analysis done with help of ANOVA. They have concluded that approach angle and rake angle are significant factors that effect on surface roughness. The large tool nose radius gives good surface finish than small tool nose radius and both generate equal tool wear. The negative rake angle gives higher compressive stress which deeper affected zone below machined surface.

(Sawant V. B. et al, 2011) have studied selection method for automated guided vehicle by using MADM methods. They have taken sixteen alternatives AGV models and nine attributes as AGV specifications and applied preference selection index (PSI) and TOPSIS MADM methods for preference selection of AGV. From result they have compared methods and average of the methods selects best AGV for the industrial application.

(Kuram E. et al, 2010),they investigate the effects of cutting fluid types and cutting parameters on surface roughness and thrust force and concluded that an increase in the spindle speed decreased the thrust force value and surface roughness value and increase in feed rate increased the force value and surface roughness value.

(Patel J., Intwala A. et al, 2014), investigated on effect of cutting parameter on drilling operation for perpendicularity and based on research paper they concluded that by using proper optimization method like Taguchi method, Design Of Experiment(DOE) and efficient software like (Mini tab 16,Analysis of variance[ANOVA]), we can obtain optimum response parameters such as surface roughness, perpendicularity, cylindricity and circularity

3. Materials and Methods

3.1 Selection of work piece material:

From the literature survey of different researchers, it has been concluded that, there is variety of materials which can be used on CNC turning operation. But among them the alloy steel is widely used in industry. So in this research work the alloy steel EN-8 is selected as work piece material. The work pieces taken for the experimental work are having 50 mm length and 35 mm diameter.

3.2 Selection of Insert:

The result of TOPSIS suggests that among the eight tool and work piece combinations the most appropriate insert for EN8 material is VBMT 16 04 08. which allow other research worker to reproduce the results. The journal will not be held responsible if any kind of plagiarism followed and the editor's decision would be final if any litigation arises during processing or after publishing.

3.3 Experimental design

The present chapter gives the application of the Full factorial experimental design method. The scheme of carrying out experiments was selected and the experiments were conducted to investigate the effect of process parameters on the output parameters e.g. Spindle speed, feed rate, depth of cut and output response as surface roughness and MRR.

3.3.1 Parameters assignment

For the present experimental work the three process parameters each at three levels have been decided. It is desirable to have three minimum levels of process parameters to reflect the true behaviour of output parameters of study. The process parameters are renamed as factors and they are given in the adjacent column. The levels of the individual process parameters/factors are given in Table 1.

Table 1 Process Parameters and their Levels

Factors	Parameters	Levels		
		L1	L2	L3
A	Speed (rpm)	1500	2200	3000
B	Feed (mm/rev)	0.15	0.20	0.25
C	Depth of cut (mm)	0.4	0.8	1.0

3.4 Full Factorial Method

Experiments have been carried out using full factorial method. Experimental design which consists of 27 combinations of spindle speed, longitudinal feed rate and depth of cut. According to the design catalogue prepared by factorial design of experiment has been found suitable in the present work. It considers three process parameters (without interaction) to be varied in three discrete levels. The experimental design has been shown in Table 2 (all factors are in coded form). Factorial design is used for conducting experiments as it allows study of interactions between factors. Interactions are the driving force in many processes.

Table 2 DOE in Coded form

Expt No	*Speed (rpm)*	*Feed (rev/min)*	*Depth Of Cut (mm)*
1	1500	0.15	0.4
2	1500	0.15	0.8
3	1500	0.15	1.0
4	1500	0.20	0.4
5	1500	0.20	0.8
6	1500	0.20	1.0
7	1500	0.25	0.4
8	1500	0.25	0.8
9	1500	0.25	1.0
10	2200	0.15	0.4
11	2200	0.15	0.8
12	2200	0.15	1.0
13	2200	0.20	0.4
14	2200	0.20	0.8
15	2200	0.20	1.0
16	2200	0.25	0.4
17	2200	0.25	0.8
18	2200	0.25	1.0
19	3000	0.15	0.4
20	3000	0.15	0.8
21	3000	0.15	1.0
22	3000	0.20	0.4
23	3000	0.20	0.8
24	3000	0.20	1.0
25	3000	0.25	0.4
26	3000	0.25	0.8
27	3000	0.25	1.0

3.5 Experimental Result:
The full factorial design experiments were conducted to study the effect of process parameters over the output response characteristics with the process parameters and interactions assigned to columns as given in Table 3. Twenty seven experiments were conducted using full factorial experimental design methodology. In the present study all the designs, plots and analysis have been carried out using Minitab statistical software.

4. Analysis of Experimental Data

4.1 Analysis of variance

The terminology of ANOVA is largely from the statistical design of experiments. The experimenter adjusts factor and measures responses in an attempt to determine an effect. Factors are assigned to experimental units by a combination of randomization and blocking to ensure the validity of the results.

Table3. Experimental Results

Expt No	*Ra Value(µm)*	*MRR (mm3/min)*
1	0.9	1.59
2	0.8	4.12
3	1.2	5.039
4	1.6	1.846
5	1.4	4.615
6	1.8	8.923
7	2.4	1.398
8	2.6	4.894
9	2.6	10.139
10	1.8	1.923
11	1.4	5.128
12	2.4	9.615
13	2.1	1.831
14	2.6	6.226
15	2.8	10.989
16	2.1	2.307
17	2.6	8.096
18	2.8	12.55
19	2.4	3.205
20	2.6	4.681
21	1.9	9.364
22	2.8	2.097
23	2.6	4.894
24	2.8	10.988
25	2.8	3.076
26	3.2	5.769
27	2.9	12.692

Analysis of Variance is a mathematical technique which breaks total variation down in to accountable sources; total variation is decomposed into its appropriate components. Once all the parameters have been decided and level values are set, experimentation is performed. The results are tabulated section wise. After the experimental results have been obtained, analysis of the results is carried out analytically as well as graphically. For graphical analysis of the experimental results plots, showing effects of all the factors upon responses, are generated in MINITAB17. Then ANOVA of the experimental data has been done to calculate the contribution of each factor in each response.

5. Results and Discussion

Analysis Results :-

5.1 Main Effects Plot for Ra value

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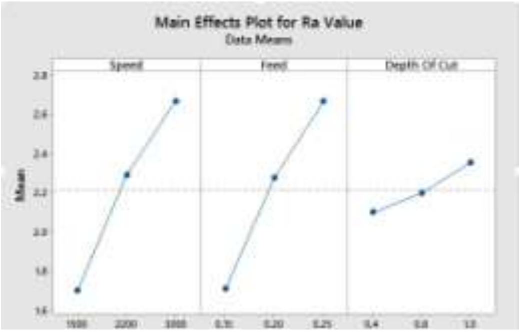

Fig 5.1 Main effects plot for Surface Roughness

Main effects plot for surface roughness of EN8 alloy steel is shown in figure 5.1 The surface roughness increases with decrease in feed and depth of cut and cutting speed.

The effects of process parameters observed are as follows:

A] Effects of Feed on Surface Roughness: It is observed that Surface Roughness decreases as feed decreases from 0.15 mm/min to 0.25 mm/min.

B] Effects of depth of cut on Surface Roughness: It observed that Surface Roughness increases as depth of cut decreases from 0.1 mm to 0.4 mm.

C] Effects of cutting speed on Surface Roughness: It is observe that surface roughness decreases as cutting speed increases from 1500 to 3000 m/min.

5.2 Main Effects Plot for Material Removal Rate

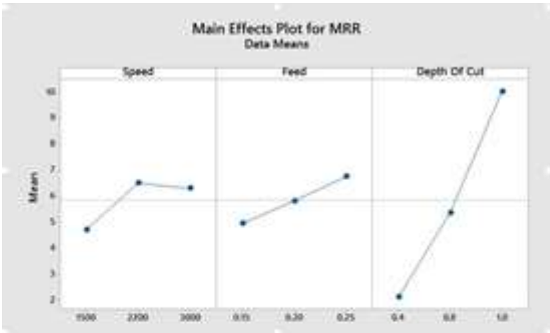

Fig 5.2 Main Effects Plot for MRR

Main effects plot for MRR of EN8 alloy steel is shown in figure 5.2. The MRR increases with increase in feed, speed and depth of cut.

The effects of process parameters observed are as follows:

A] Effects of Feed on Material Removal Rate: It is observed that Material Removal Rate increases as feed increases from 0.15 mm/rev to 0.25 mm/rev.

B] Effects of Depth of cut on Material Removal Rate: It is observed that as Material Removal Rate as depth of cut increases from 0.4 mm to 1.0mm.

C] Effects of cutting speed of Cut on Material Removal Rate: It is observe that MRR decreases as cutting speed increases from 2000 to 3000 rpm and MRR is increases as cutting speed increases from 1500 to 2000 rpm.

5.3 Interaction Plot for Ra value & MMR

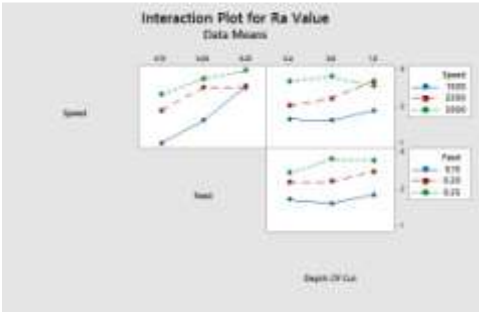

Fig 5.3 Interaction Plot for Surface Roughness

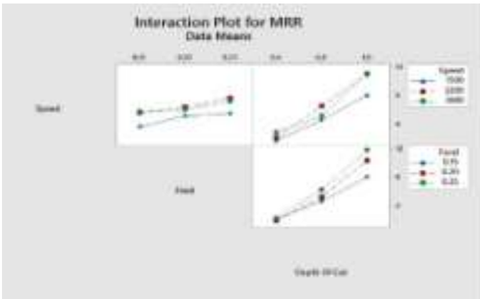

Fig 5.4 Interaction Plot for Material Removal Rate

6. Conclusions

1. The result of TOPSIS suggests that among the eight tool and work piece combinations the most appropriate insert for EN8 material is VBMT 16 04 08.
2. The result shown in Table 4 suggests that we get maximum surface finish at a speed of 1500 rpm, feed of 0.15 mm/rev and for a depth of cut 0.8 mm.
3. The result shown in Table 4 suggests that we get a maximum material removal rate of 12.6923 kg/min at a speed of 3000rpm, feed of 0.25 mm/rev and 1 mm of depth of cut.
4. Thus, the input factors used in the above experiment are very effective to obtain high surface finish and material removal rate by using VBMT tool for EN8 material.

Appendix

Table 4:- Chemical composition of EN8 material

Element	Weight(%)
C	0.36-0.44
Si	0.10-0.40
Mn	0.60-1.00
P	0.05
S	0.05

Insert used:-VBMT 16 04 08

1. V – Insert shape (included angle 350)
2. B – insert clearance angle – 5 deg
3. M – Tolerance
4. T – insert type
5. 16 – insert size
6. 04 – insert thickness = 4 mm
7. 08 – nose radius = 0.8 mm

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