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Optimization of machining Parameters in CNC machining of D2 Steel Using Taguchi Method

Umar Siddique
Dual Degree Student
Department of Mechanical Engineering
Engineering Integral University, Lucknow,
,U.P.(India)

Mohd. Faizan Hasan
Assistant Professor
Department of Mechanical
Integral University, Lucknow
U.P.(India)

Abstract

The goal of this project is to machine D2 steel using CNC turning and to research the influencing parameters of surface roughness and MRR during machining materials. The MRR and Surface roughness of the CNC Turning process parameters of feed rate, depth of cut, spindle speed/rotational speed, and lubrication have been examined. For the experiments, a carbide tip tool was employed as a cutting tool. Taguchi's L18 mixed type orthogonal array experimental design was chosen for inquiry, and Taguchi's technique was used to optimise the design, as well as analysis of variance (ANOVA) to determine the relevance of process factors on the response variable.

I. INTRODUCTION

Any manufacturing industry in the world strives to fulfil two key goals: quality and client requirements. In any industrial industry, machining is one of the most important metal processing procedures. Many process parameters influence the quality of metal cutting. The output responsiveness or performance qualities are influenced by these process factors. As a result, selecting the right process parameter is crucial in machining processes. Poor process parameter selection leads to non-optimal machine operation, resulting in poorer material removal rate, lower surface finish, longer machining time, shorter tool life, greater tool wear, and higher energy consumption, among other things. For example, there are numerous process parameters in a turning operation [cutting parameters, cutting tool parameters, work piece material (surface and temperature), ambient characteristics, and so on]. The turning operation is the most extensively utilised machining operation, and the current industrial condition necessitates researchers to develop improved process parameters to offer high-quality products while conserving energy. Various metrics like as feed and radial forces, Ra, tool wear, and work piece temperature are used to evaluate the machinability of materials in turning.

The current research focuses on machining stainless steel on a turning centre while optimising machining parameters.

Stainless steel is a low-density, corrosion-resistant, and long-lasting material with unique properties such as ease of joining, casting ease, high thermal conductivity, and formability.

D2 steel was chosen because it is widely employed in a variety of manufacturing industries for a wide range of applications.
Taguchi method, ANOVA methodology, fuzzy logic, and genetic algorithms are some of the optimization methods used.

algorithm and so on. ANOVA and the Taguchi technique are two of the most used approaches. The ANOVA is a statistical test that compares two groups

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The Taguchi approach aids in determining which parameter is most important for given input parameters, whereas the technique aids in determining which parameter is most significant for given input parameters.

Using this method, you can find the best condition with less experiments.

1.1. Turning process

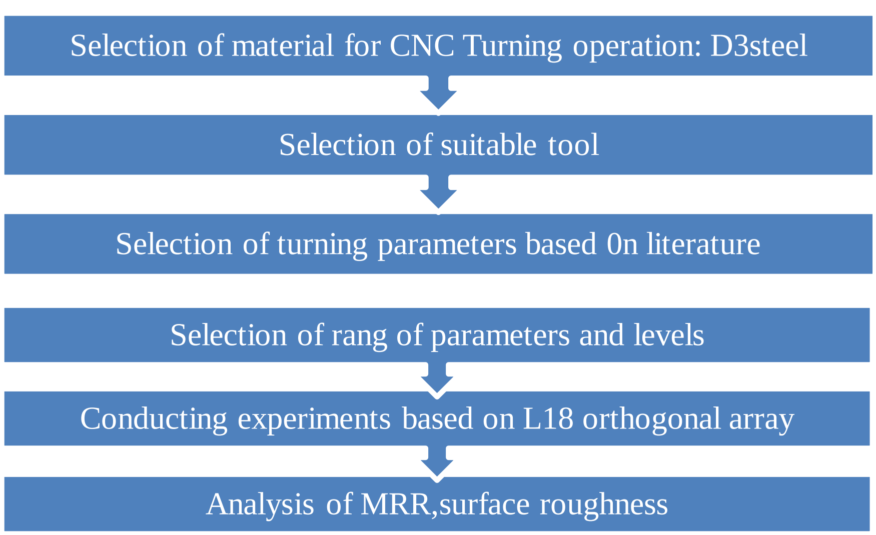
- Step Turning
- Face Turning
- Eccentric Turning
- Straight Turning
- Shoulder Turning
- Taper Turning

1.2. D2 Steel

D2 belongs to the "high carbon, high chromium" steels category of tool steels. The discovery of ferrochromium in 1821 and the development of low carbon ferrochromium in 1895 resulted in the production of chromium-alloyed steel possible.

	C (%)	Cr (%)	Mo (%)	V (%)
D3	2.2	12		
D2	1.5	12	0.8	0.6

Methodology



Developing statistica analysis by ANOVA

Analysis of results

Analysis of conclusion

1.4. Development of D2

Paul Kuehnrich [5] submitted a patent in England in 1918 for a high carbon, high chromium steel with a 3.5 percent cobalt content. The cobalt was added to improve the steels' hot toughness, bringing them closer to high-speed steel. In this page, you may learn more about the effects of cobalt on steel. The chemical ranges in the patent are fairly broad: 1.2-3.5 percent carbon, 8-20 percent chromium, and 1-6 percent cobalt. However, the example alloy offered included 1.5 percent C, 12 percent Cr, and 3.5 percent cobalt, which would be quite close to current D2 without the cobalt.

Properties of D2

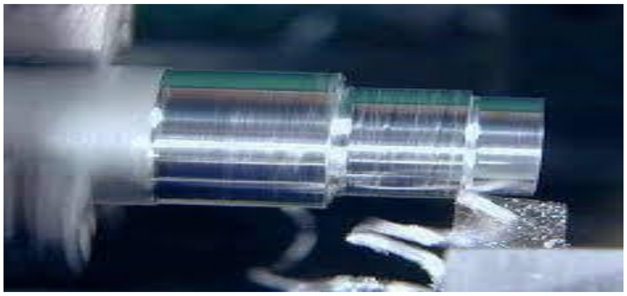
With CATRA testing, Bohler Uddeholm showed that D2 had somewhat better edge retention than N690, ATS-34/154CM, and 440C, was on par with 3V, but was poorer than S35VN, Vanadis 4 Extra, Elmax, S30V, M4, and M390 [11]. I also analysed edge retention in comparison to 440C, a value that Crucible has previously reported.

Steel	Hardness (Rc)	Edge Retention	% of 440C
M390	61+	958.6	179
Elmax	62	930.7	174
M4	61	899.7	168
S30V	61	798	149
Elmax	60+	761.7	142
Vanadis 4 Extra	61	708.9	132
S35VN	61	706.6	132
3V	61	674.4	126
D2	**61**	**665.8**	**124**
N690	61+	635.1	118
ATS-34/154CM	61+	546.9	102
440C	59	536	100

CNC Lathe machine

ACE-CNC The turning machine used in this study is illustrated in Fig. and the machine specifications are mentioned below. Figures 1 and 3 illustrate the D2 Steel component that has been machined or turned.

D2 steel befoe machining



D2 steel after machining

Taguchi method

In the late 1940s, Dr. Genechi Taguchi conducted useful research using DOE technologies. He put in a lot of effort and time to make this exploratory technique more understandable, and he connected this system to improve the quality of manufactured goods. Dr. Taguchi's institutionalised kind of DOE, sometimes referred to as the Taguchi strategy or Taguchi's method, was first introduced in the United States in the mid-1980s. It is now one of the most popular and high-quality tools used by designers in a variety of assembly tasks. Two, three, and blended level fragmented factorial designs are used in this technique. Taguchi disciples appear to be particularly supportive of broad screening outlines. Taguchi diagrams make use of orthogonal clusters to separate the effects of elements on the response MRR and surface. The design is changed using an orthogonal cluster with the purpose of weighting variable levels similarly.

Table . Control Parameters and their levels;

Parameter	Factor	Level 1	Level 2	Level 3
Lubrication	A	Dry	Coolant	...
Feed rate (mm/rev)	B	0.1	0.2	0.3

Depth of cut (mm)	C	0.2	0.3	0.4
Rotational speed (rpm)	D	500	1000	1500

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Signal to noise ratio

The noise to signal ratio, which was proposed by Dr. Taguchi for resilient design, is an effective instrument for quantifying the quality of the product response to noise ratio and signal factor. For the product response, the signal to noise ratio can be classified into three categories: lower is better, higher is better, and nominal is best.

Smaller is the better.

Surface roughness is examined in this study within the category of smaller is better, and the equation (1) was utilised to calculate it. -10log [Ra2] signal-to-noise ratio ———————————————————- (1)

Higher the better.

The higher the signal to noise ratio, the better the material removal rate, which may be computed using equation (2)

-10log [1/MRR2] signal-to-noise ratio

Analysis of variance (ANOVA)ample appendix

The relevance of machining parameters on output responses like material removal rate and surface roughness is estimated using analysis of variance. The significance of process parameters is determined by comparing the 0.05 level of 95 percent confidence with the p-value column; if the p-value is less than 0.005, the process parameter is significant; if the p-value is greater than 0.005, the process parameter is insignificant; and the ANOVA table displays the influencing parameters on response.

Table : List of input parameters and output response

Sl NO	Input parameters	Sl No	Output response
01	Lubrication	01	Material removal rate (mm3/min)
02	Feed rate (mm/min)	02	Surface roughness (micro meter)

03	Depth of cut (mm)	**…**	**…**
04	Rotational speed (rpm)	**…**	**…**

Table a. L18 orthogonal array (21x 37); b. L18 orthogonal array; c. Response table;

a) **b)**

Exp No	**Lubrication**	**Feed rate (mm/rev)**	**Depth of cut (mm)**	**Rotation speed (rpm)**	**Exp No**	**Lubrication**	**Feed rate (mm/rev)**	**Depth of cut (mm)**	**Rotation Speed (rpm)**
01	1	1.5	1.5	1.5	01	Dry	0.2	0.3	500
02	1	1.5	2.5	2.5	02	Dry	0.2	0.4	1000
03	1	1.5	3.5	3.5	03	Dry	0.2	0.5	1500
04	1	2.5	1.5	1.5	04	Dry	0.4	0.3	500
05	1	2.5	2.5	2.5	05	Dry	0.4	0.4	1000
06	1	2.5	3.5	3.5	06	Dry	0.4	0.5	1500
07	1	3.5	1.5	1.5	07	Dry	0.6	0.3	500
08	1	3.5	2.5	2.5	08	Dry	0.6	0.4	1000
09	1	3.5	3.5	3.5	09	Dry	0.6	0.5	1500
10	2	1.5	1.5	1.5	10	Coolant	0.2	0.3	500
11	2	1.5	2.5	2.5	11	Coolant	0.2	0.4	1000
12	2	1.5	3.5	3.5	12	Coolant	0.2	0.5	1500
13	2	2.5	1.5	1.5	13	Coolant	0.4	0.3	500
14	2	2.5	2.5	2.5	14	Coolant	0.4	0.4	1000
15	2	2.5	3.5	3.5	15	Coolant	0.4	0.5	1500
16	2	3.5	1.5	1.5	16	Coolant	0.6	0.3	500
17	2	3.5	2.5	2.5	17	Coolant	0.6	0.4	1000
18	2	3.5	3.5	3.5	18	Coolant	0.6	0.5	1500

c)

Exp No	**MRR (mm3/min)**	**Surface roughness (Micro meter)**	**Signal to noise for MRR (dB)**	**Signal to noise for Ra(dB)**
01	785.224	3.31	60.3256	-11.3654
02	2030.254	2.01	67.6987	-4.2354
03	3975.987	1.02	73.3215	-0.2587
04	1763.354	4.98	66.1542	-14.3256
05	4012.321	2.50	73.2598	-8.3214
06	7025.636	2.23	78.2358	-8.2189
07	4155.656	5.25	73.3145	-15.3214
08	7654.213	4.98	78.1289	-14.2589
09	4254.635	5.20	73.3587	-15.2135
10	23254.231	2.21	68.1258	-5.2145
11	1198.398	2.32	62.1238	-4.9898
12	2842.325	0.89	70.1254	-3.2145
13	2795.398	3.12	70.7845	-10.2315
14	5208.910	1.97	75.2154	-6.1202
15	3141.201	3.12	71.2569	-12.2102
16	5021.145	4.55	75.6589	-12.9850
17	2466.587	4.78	68.2365	-13.9858
18	9554.215	4.36	80.2548	-14.9852

Effect on material removal rate

The influence on the rate of material removal has been plotted, as shown in Fig. According to the graph, feed rate, depth of cut, and rotational speed all have a direct effect on material removal rate, while lubrication has an inverse relationship with material removal rate; this implies that when the machine is dry, the material removal rate is higher than when it is coolant. The MRR increases as the feed rate, depth of cut, and rotational speed are increased, and the best process parameters for obtaining maximum MRR are noted as A1-B3-C3-D3 (Dry-0.3mm/rev-0.4mm-1500rpm). The Fig has been given response table for MRR, from the table. The feed rate has the greatest impact on the rate of material removal, followed by rotating speed, depth
of cut, and lubrication. Table 5 shows the significance of process parameter on response variable in the analysis of variance table.see that feed rate and rotational speed has significant effect on material removal rate and remaining parameters are

insignificant. The p values of process parameters are less than 0.005(α=0.005) 95 percent of confidence level then it is stated as significant or more than 0.005 it is insignificant.

RESULTS & DISCUSSIONS

In the previous chapter, L18 ANOVA was used to run experiments and evaluate output responses such as material removal rate and surface roughness. In this chapter, the experimental data is examined and machining parameters are adjusted using the Taguchi optimization technique.

Fig 4. Main effect plots for MRR

Table 4. Response Table for MRR

Level 18	**Lubrication**	**Feed rate**	**Depth of cut**	**Rotational speed**
1	4025	2172	2789	2380
2	3845	4018	3863	4325
3	-	5488	5228	5365
Delta	165	3410	2365	2926
Rank	4	1	3	2

Effect on surface roughness

The effect of input parameters on surface roughness has been observed in Fig. From the Fig 5, it can be concluded that machining under coolant conditions produces lower surface roughness, that increasing feed rate increases surface roughness, that increasing depth of cut rotational speed decreases surface roughness, and that the optimal setting parameters for achieving lower Ra are A2-B1-C3- D3(Coolant-0.1mm/rev-0.4mm-1500).

Table 6. Response Table for surface roughness

Level	lubrication	Feed rate	Depth of cut	Rotational speed
1	3.520	1.650	3.710	4.205
2	3.216	3.102	3.825	3.850
3	-	5.102	3.104	2.120
Delta	0.312	2.985	1.100	1.523
Rank	4	1	3	2

Table 7. Analysis of variance for surface roughness

Source	DF	Adj D2 steel	Adj MS	F-Value	P-Value	Remark
Lubrication	1	0.5245	0.4769	2.20	0.214	Insignificant
Feed rate	2	31.2598	15.3258	86.23	0.001	Significant
Depth of cut	2	3.1021	1.2369	6.87	0.014	Insignificant
Rotational speed	2	6.9587	3.2148	16.98	0.002	Ssignificant
Error	10	2.2010	0.3259	-	-	-
Total	17	42.1489	-	-	-	-

Conclusion

The influence of lubrication, feed rate, depth of cut, and rotating speed on response has been explored in this research work for EN 19 steel, and the effect of lubrication, feed rate, depth of cut, and rotational speed on response has been researched under L18. ANOVA is used to examine Taguchi's orthogonal array and the significance of process characteristics.

The following are some key findings from this research.

- In comparison to coolant machining, the material removal rate increases with increases in feed rate, MRR, depth of cut, and spindle speed.
- Surface roughness decreases as the depth of cut and spindle speed increase; however, by lowering the feed rate, the Ra can be reduced, and the surface roughness can be minimised under coolant conditions.

- Both M R R and surface roughness are affected by feed rate and spindle speed.
- Material removal rate and surfac6 roughness are unaffected by lubrication or cut depth.
- A1- B3-C3-D3 (Dry0.3mm/rev-0.4mm-1500rpm) and A2-B1-C3-D3 (Coolant- 0.1mm/rev-0.4mm-1500rpm) are the anticipated ideal setup parameters for M R R and surface roughness, respectively.
- The findings of the confirmation test show a 13.213 percent increase in MRR and a 24.891 percent reduction in surface roughness.

Scope for Future Work

- Different orthogonal array experiments, such as L16, L27, and others, can be carried out.
- Tool wear can be taken into consideration while optimising CNC turning.
- It is possible to conduct an Ansys Modeling analysis.
- Scanning electron microscopy can be used to investigate surface integrity and analyse microstructure.

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