Analysis of Turning Parameters of Aluminium Alloy 7075 using different tool geometry

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ABSTRACT

Almost 80% of a commercial & Army airframe is made of aluminium alloys. It is assumed that the usage of aluminium alloy is to increase up to 70% by the year 2025. A lot of literature were studied to minimize this critical issue. This project presents a study of the cutting tool recital of a Coated TNMG Carbide & Uncoated TNMG carbide tool in operation on Al 7075, in which the volume of material removed and surface roughness were examined. The machining tests were conducted on a CNC lathe machine to obtain the MRR and surface roughness of the Aluminium Alloy 7075 workpiece material. The average surface roughness (Ra) was measured using a surface roughness sample. Based on the results. The effect of these cutting parameters on each of these variables was examined, as well as the possible interrelation between them. The experimental results exposed that the mechanical special effects, formed by the feed, should not be abandoned against the thermal effects, formed by the cutting speed, contained by the range of the tested cutting speed.

Keywords: Surface Roughness, Cutting tool, Tool Insert, Material Removal Rate.

1. INTRODUCTION

CNC Metal cutting is one of the most used engineering processes, and its advancement in technology lasts to progress in material science growth. The productivity and efficiency of the metal removal processes depend on machining parameters such as cutting conditions, cutting tool geometry as well as the workpiece and tool material[(1)]. The main significance of this research is to forecast the surface roughness and MRR using the Taguchi method during turning of AA7075 by optimizing the parameters like cutting speed, feed rate, & depth of cut to attain good surface roughness. From the literature survey, it is detected that many research used using ANN method to optimize surface roughness.

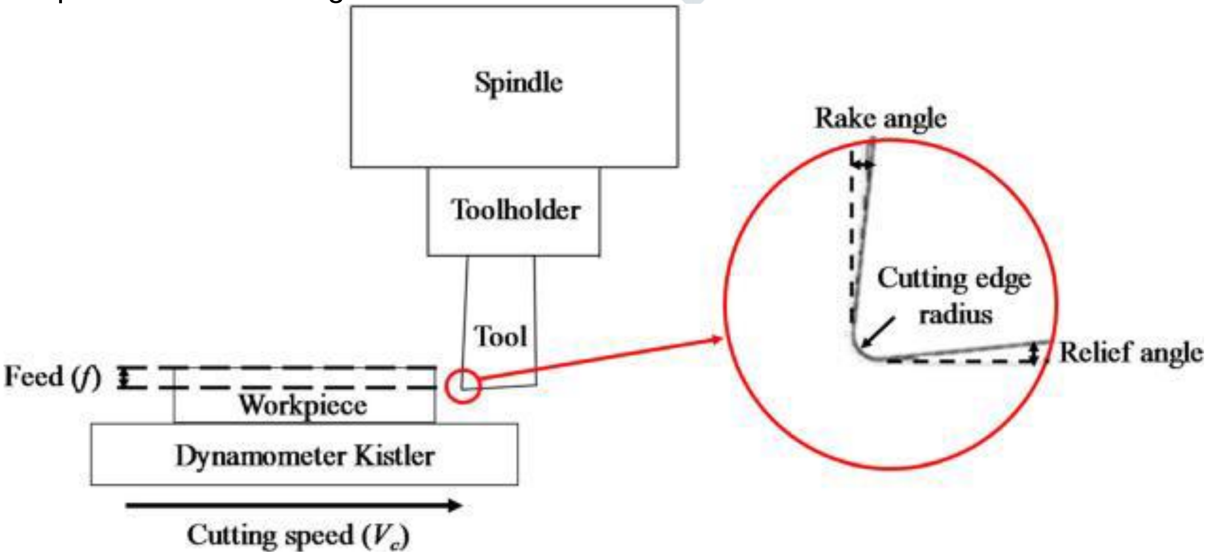


Fig 1. Orthogonal Linear Set up

In this experimental work an alloy of Aluminium Al 7075 which is most commonly used in aeronautical and manufacturing industries has been taken as a material for investigation and the effect of cutting speed, feed and depth of cut on surface roughness using the Taguchi method is considered. Despite the lack of research studying the cutting parameter influence on corrosion behaviour of machined parts, several studies revealed that low cutting speed and high feed values result in machined parts with lower corrosion resistance. [2-4] To overcome these hurdles, researchers around the globe are concentrating on alternate technologies such as improved tool materials and advanced cutting technologies with improved machining environments such as dry and minimum quantity lubrication (MQL) [6-8]. Therefore, an analysis of cutting speed and feed influence on surface roughness of 7075 alloys, turned, was carried out in with this work. The influence of these cutting parameters on each of these variables (surface roughness, & MRR) was analysed, as well as the possible interrelation between them. These experimental results have been analysed using Taguchi.

2. MATERIAL

2.1 WORKPIECE MATERIAL

The workpiece material used in the machining tests was a 25mm x 80 mm Al 7075 round rod. The chemical composition and mechanical properties of the work material are given in Table 1 and Table 2, respectively.

Table: 01

Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Other
0.04	0.10	1.3	0.07	2.3-2.4	0.10	6.7-6.8	0.05	Balance

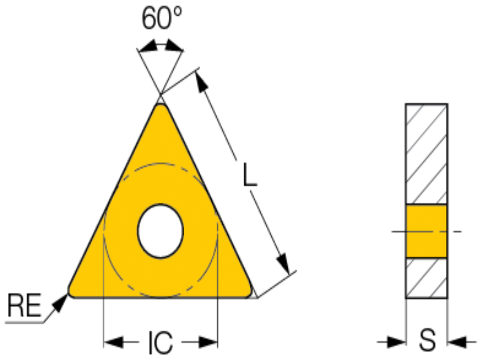
Table: 02

Properties	**Values**
Tensile Strength (KSI)	78-85
Yield Strength (KSI)	68-78
Elongation (%)	7-12

A round bars (diameter, D = 25 mm; length, L = 80 mm) were used to manufacture the specimens. A length of 30 mm was turned as the surface Roughness Measurement. A new tool was used in this last operation, to ensure the same initial conditions. The machining operations were carried out in a CNC turning centre.

2.2 TOOL GEOMETRY

The cutting tool used was,



I. TNMG Coated carbide tool
II. TNMG Uncoated carbide tool

This cutting tool is suitable for use in cutting non-ferrous material such as Al 7075 for medium to finishing operations.

3. METHODOLOGY

In this research work analysis of variance (ANOVA) using the Taguchi method have been used for the optimization of speed, feed rate and depth of cut and to study its effects on surface roughness. The material used for the study is aluminium alloy Al 7075. The machining tests were conducted on the ACE IGLOO SUPER JOBBER 500LM CNC lathe machine and the useful specifications of the machine are as shown in Table 3

Table: 03

Capacity	
Swing over bed	500 mm
Maximum turning length	300 mm
Maximum turning dia	320 mm
Standard dia	165 mm
Slides	
Cross (x-axis) travel	165 mm
Longitudinal (z-axis) travel	300 mm
Rapid feed (x & Z-axis)	30 M/min
Main Spindle	
Spindle motor power	5.5kw/10.5kw (30 min. Rating)
Spindle bore	52.5 mm
Spindle nose	$A_2$5
Max. Bar capacity	25(36)* mm
Speed range	50 – 4000 rpm
Full power speed range	1000 – 4000 rpm
Turret	
No. of Station	8
Max. Boring Bar Dia.	40
Tool Size	25 mm x 25 mm
Accuracy	
Positioning	0.015mm
Repeatability	+/-0.003mm

Weight (approx.)	2500 kg
Dimension (approx.)	2020 mm x 1640 mm x 1985 mm
Tool Holder	MTJNL 2525 M16

4. Design of Experiments

The turning operation was conducted in dry conditions using an ACE IGLOO SUPER JOBBER 500LM CNC lathe machine. The parameters and values used in the experiment are shown in Table 4.

Table: 04

Parameters	Level 1	Level 2	Level 3
Cutting speed	800	1150	1400
Feed rate	0.1	0.15	0.2
DOC	0.25	0.75	1.5

The average surface roughness of Workpiece (Ra) was measured using a Mitutoyo Surf test surface roughness tester.

Then, the MRR was examined by measuring the weight of turned chip to determine the MRR and Time for turning that occurred during the machining operation.

I. Surface Roughness and MRR Analysis for TNMG COATED INSERT.

The optimization of the control factors after performing the turning operation was done using Minitab 18 software. The corresponding experimental for the TNMG COATED plan is as shown in Table 05. The signal to noise ratio (S/N) for surface roughness values was calculated using smaller-the-better characteristics as per Taguchi's L27 orthogonal array. The corresponding S/N ratio shown as delta is as shown for TNMG COATED in Table 06. From this table, it is analysed that the feed rate is the most effective variable on surface roughness as compared to spindle speed and depth of cut.

TABLE: 05

TNMG COATED					
EXP NO.	**Spindle Speed**	**Feed Rate**	**Depth of Cut**	**Surface Roughness**	**MRR**
	rpm	**mm/rev**	**mm**	**µm**	**gm/sec**
TC01	800	0.1	0.25	0.79	0.114286
TC02	800	0.1	0.75	1.04	0.304762
TC03	800	0.1	1.5	1.4	0.457143
TC04	800	0.15	0.25	1.78	0.171527
TC05	800	0.15	0.75	1.75	0.400229
TC06	800	0.15	1.5	2.31	0.686106
TC07	800	0.2	0.25	3.2	0.228571
TC08	800	0.2	0.75	3.18	0.380952
TC09	800	0.2	1.5	3.36	0.990476
TC10	1150	0.1	0.25	0.86	0.164294
TC11	1150	0.1	0.75	0.86	0.438116
TC12	1150	0.1	1.5	1.94	0.711939
TC13	1150	0.15	0.25	1.74	0.246508
TC14	1150	0.15	0.75	1.75	0.246508
TC15	1150	0.15	1.5	1.55	0.986031
TC16	1150	0.2	0.25	3.14	0.328587
TC17	1150	0.2	0.75	3.16	0.438116
TC18	1150	0.2	1.5	3.32	1.09529
TC19	1400	0.1	0.25	0.78	0.2

TC20	1400	0.1	0.75	0.82	0.466667
TC21	1400	0.1	1.5	1.55	0.866667
TC22	1400	0.15	0.25	1.82	0.3003
TC23	1400	0.15	0.75	1.72	0.800801
TC24	1400	0.15	1.5	1.67	1.101101
TC25	1400	0.2	0.25	3.22	0.4
TC26	1400	0.2	0.75	3.06	0.933333
TC27	1400	0.2	1.5	2.49	1.6

Figure 3 (a) and 3(b) shows the data means and main effect plots for S/N ratios of Surface Roughness. The main objective of S/N ratios is to analyse the performance measurement to develop a product. The process parameters with the smallest signal to noise ratio produce the optimum quality with minimum alteration.

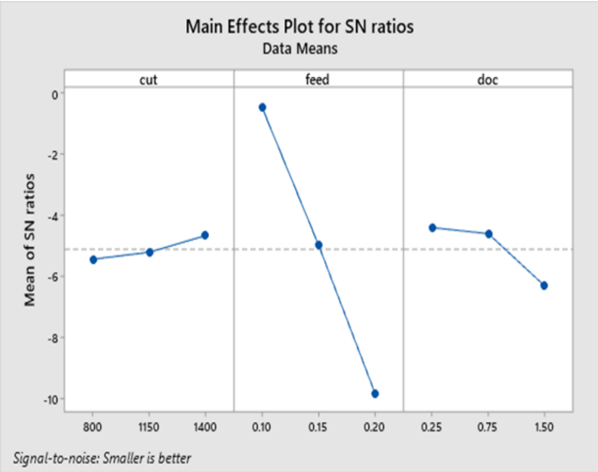


Figure: 03(a)

Figure: 03(b)

TABLE: 06

Response Table for Signal to Noise Ratios

Smaller is better

Level	Spindle Speed	Feed	DOC
1	-5.4484	-0.4752	-4.4115
2	-5.2188	-4.9985	-4.6106
3	-4.6763	-9.8699	-6.3213
Delta	0.7721	9.3947	1.9098
Rank	3	1	2

TABLE: 07

Analysis of Variance for SN ratios

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Spindle Speed	2	2.829	2.829	1.415	0.48	0.624
Feed	2	397.355	397.355	198.677	67.75	0.000
DOC	2	19.840	19.840	9.920	3.38	0.054
Residual Error	20	58.652	58.652	2.933		
Total	26	478.676				

Table 07 shows the analysis of variance (ANOVA) for S/N ratios of Surface Roughness. From the results of Minitab software, it is observed that for turning of aluminium alloy 7075, the spindle speed contributed 0.59% and feed rate and depth of cut contributed 83.01% and 4.14% considering significant interaction effect between spindle speed and depth of cut.

Figure 4 (a) and 4(b) shows the data means and main effect plots for S/N ratios of MRR. The main objective of S/N ratios is to analyse the performance measurement to develop the product. The process parameters with the smallest signal to noise ratio produce the optimum quality with minimum alteration.

Figure 4(a)

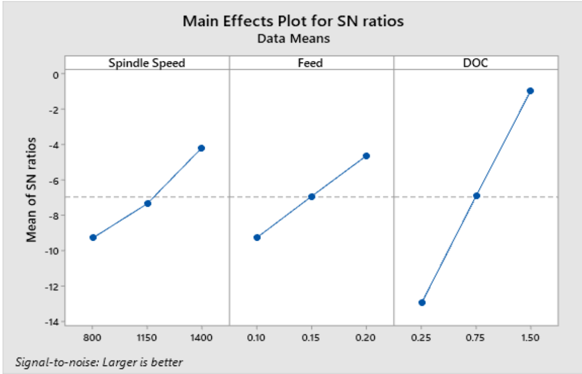


Figure 4(b)

TABLE: 08

Response Table for Signal to Noise Ratios

Larger is better

Level	Spindle Speed	Feed	DOC
1	-9.3094	-9.2899	-12.9865
2	-7.3667	-6.9478	-6.9229
3	-4.2066	-4.6451	-0.9734
Delta	5.1028	4.6448	12.0130
Rank	2	3	1

TABLE: 09

Analysis of Variance for SN ratios

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Spindle Speed	2	119.39	119.39	59.697	20.26	0.000
Feed	2	97.09	97.09	48.544	16.48	0.000
DOC	2	649.43	649.43	324.713	110.21	0.000
Residual Error	20	58.93	58.93	2.946		
Total	26	924.84				

Table 09 shows the analysis of variance (ANOVA) for S/N ratios of Material Removal Rate. From the results of Minitab software, it is observed that for turning of aluminium alloy 7075, the spindle speed contributed 12.91% and feed rate and depth of cut contributed 10.50% and 70.22% respectively. Considering significant interaction effect between spindle speed and Feed Rate.

II. Surface Roughness and MRR Analysis for TNMG UNCOATED INSERT.

The optimization of the control factors after performing the turning operation was done using Minitab 18 software. The corresponding experimental for TNMG UNCOATED plan is as shown in Table 10. The signal to noise ratio (S/N) for surface roughness values was calculated using smaller-the-better characteristics as per Taguchi's L27 orthogonal array. The corresponding S/N ratio shown as delta is as shown for TNMG UNCOATED in Table 11. From this table, it is analysed that the spindle speed is the most effective variable on surface roughness as compared to feed rate and depth of cut.

TABLE: 10

TNMG UNCOATED					
EXP NO.	Spindle Speed	Feed Rate	Depth of Cut	Surface Roughness	MRR
	rpm	mm/rev	mm	μm	gm/sec
TUC01	800	0.1	0.25	0.86	0.114286
TUC02	800	0.1	0.75	0.87	0.266667
TUC03	800	0.1	1.5	0.68	0.457143
TUC04	800	0.15	0.25	1.88	0.171527
TUC05	800	0.15	0.75	1.59	0.400229
TUC06	800	0.15	1.5	1.85	0.400229
TUC07	800	0.2	0.25	3.31	0.228571
TUC08	800	0.2	0.75	3.06	0.609524
TUC09	800	0.2	1.5	3.74	0.609524
TUC10	1150	0.1	0.25	0.92	0.164294
TUC11	1150	0.1	0.75	0.94	0.219058
TUC12	1150	0.1	1.5	0.91	0.657174
TUC13	1150	0.15	0.25	1.87	0.246508

TUC14	1150	0.15	0.75	1.83	0.657354
TUC15	1150	0.15	1.5	1.61	0.821693
TUC16	1150	0.2	0.25	3.27	0.328587
TUC17	1150	0.2	0.75	3.72	0.876232
TUC18	1150	0.2	1.5	3.44	1.423877
TUC19	1400	0.1	0.25	0.87	0.266667
TUC20	1400	0.1	0.75	1.24	0.466667
TUC21	1400	0.1	1.5	2.18	0.866667
TUC22	1400	0.15	0.25	1.87	0.3003
TUC23	1400	0.15	0.75	1.89	0.800801
TUC24	1400	0.15	1.5	4.43	1.201201
TUC25	1400	0.2	0.25	3.29	0.4
TUC26	1400	0.2	0.75	3.25	0.933333
TUC27	1400	0.2	1.5	3.54	1.466667

Figure 5(a) and 5(b) shows the data means and main effect plots for S/N ratios of Surface Roughness. The main objective of S/N ratios is to analyse the performance measurement to develop the product. The process parameters with the least signal to noise ratio yield the optimum quality with minimum variance.

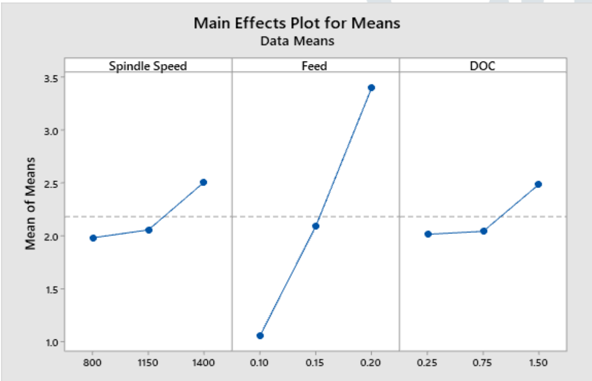


Figure:5(a)

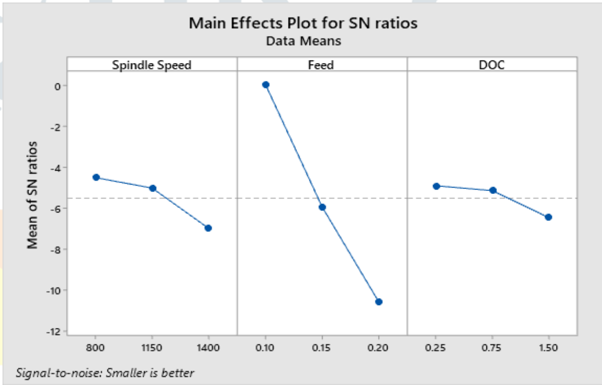


Figure: 5(b)

TABLE: 11

Response Table for Signal to Noise Ratios

Smaller is better

Level	Spindle Speed	Feed	DOC
1	-4.5059	0.0580	-4.9049
2	-5.0194	-5.9523	-5.1434
3	-6.9871	-10.6181	-6.4641
Delta	2.4811	10.6762	1.5592
Rank	2	1	3

TABLE: 12

Analysis of Variance for SN ratios

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Spindle Speed	2	30.87	30.87	15.437	3.71	0.043
Feed	2	515.62	515.62	257.812	61.98	0.000
DOC	2	12.70	12.70	6.348	1.53	0.242
Residual Error	20	83.19	83.19	4.159		
Total	26	642.38				

Table 12 shows the analysis of variance (ANOVA) for S/N ratios of Surface Roughness. From the results of Minitab software, it is observed that for turning of aluminium alloy 7075, the spindle speed contributed 4.80% and feed rate and depth of cut contributed 80.26% and 1.98% considering significant interaction effect between spindle speed and depth of cut.

Figure 6(a) and 6(b) shows the data means and main effect plots for S/N ratios of MRR. The main objective of S/N ratios is to analyse the performance measurement to develop the product. The process parameters with the smallest signal to noise ratio produce the optimum quality with minimum alteration.

Figure: 6(a)

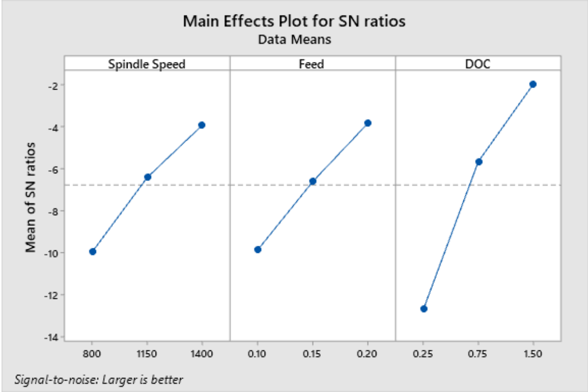


Figure: 6(b)

TABLE: 13

Response Table for Signal to Noise Ratios

Larger is better

Level	Spindle Speed	Feed	DOC
1	-9.973	-9.887	-12.709
2	-6.420	-6.613	-5.652
3	-3.929	-3.822	-1.962
Delta	6.044	6.065	10.747
Rank	3	2	1

TABLE: 14

Analysis of Variance for SN ratios

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Spindle Speed	2	166.10	166.10	83.050	29.33	0.000
Feed	2	165.91	165.91	82.953	29.29	0.000
DOC	2	536.72	536.72	268.360	94.76	0.000
Residual Error	20	56.64	56.64	2.832		
Total	26	925.36				

Table 14 shows the analysis of variance (ANOVA) for S/N ratios of Material Removal Rate. From the results of Minitab software, it is observed that for turning of aluminium alloy 7075, the spindle speed contributed 17.94% and feed rate and depth of cut contributed 17.93% and 58% respectively. Considering significant interaction effect between spindle speed and Feed Rate.

5. Results & Discussion

In this chapter analysis is carried out using Minitab software for the influence of process parameter over response such as MRR and Surface roughness with the help of Taguchi method was discussed.

The Taguchi method suggested two different routes carry out the complete analysis. First, the standard approach, where the results of a single run, or the average of repetitive runs, are processed through main effect and ANOVA analyses as identified above. The second approach, which he strongly recommended for multiple runs, is to use signal ratio (S/N) for the same steps in the analysis.

The Signal-to-Noise ratio is also one more contribution of Taguchi. Minitab software help to calculate S/N ratio based on required response and provide response table and response plot for deciding significant parameter.

There are many different S/N ratios. The important (basic) S/N ratios are:

A. Larger-the-Better for MRR.

It is used where the largest value is wanted, such as weld strength, gasoline mileage, or yield. From a mathematical viewpoint, the target value is 00, as the loss function. It is the reciprocal of smaller the-better. The equation is:

$$SN = -10 \log \left[\frac{1}{N}\left(\sum \mathrm{y_i}^2\right)\right]$$

B. Smaller-the-Better for Surface Roughness.

The S/N ratio for smaller the-better is used for situations where the target value is zero, such as computer response time, automotive emission, or corrosion. The equation for the smaller-the-better ratio is:

$$SN = -10\log\left[\frac{1}{N}\left(\sum y_i^2\right)\right]$$

In this research work, CNC turning operation have been performed on aluminium alloy 7075 material and the surface roughness have been measured by considering machining parameters such as spindle speed, feed rate and depth of cut. The optimization of the process has been performed using analysis of variance (ANOVA). Based on this research work, the following results have been drawn.

1. The effective prediction of the surface roughness of the material for various machining parameters (cutting speed, feed rate, depth of cut etc. as input variables) have been analysed.
2. While Cutting with TNMG coated insert, for lower cutting speeds, as the cutting speed increases, the surface roughness values decrease. Also, for higher feed rates the surface roughness values change considerably
3. Based on ANOVA results, feed rate has a significant impact on surface roughness as compared to spindle speed and depth of cut.
5. While Cutting with TNMG uncoated insert, for lower cutting speeds, as the cutting speed increases, the Material Removal Rate values decrease.
6. Based on ANOVA results, depth of cut has a significant impact on material removal rate as compared to spindle speed and feed rate.
7. This method of optimization of surface roughness in turning of Al 7075 techniques using the Taguchi method can be further studied for different materials.

6. Conclusion

This study presented an efficient method for determining the optimal turning operation parameters for a surface finish under varying conditions through the use of the Taguchi parameter design process. This process was applied using a specific set of control and noise parameters, and a response variable of surface roughness and MRR. For the experimentation L27, an orthogonal array was used with five control parameters. The study found that the control factors had varying effects on the response variable, cutting condition is not significant for material removal rate but significant for surface roughness; dry cutting is better than wet cutting condition. Spindle speed and depth of cut is a less significant parameter for both MRR and Surface roughness in both conditions. Feed rate is a more significant parameter following tool nose radius for the surface roughness. Tool nose radius is a more significant parameter following the material removal rate. The numerous combinations of design parameter settings cannot efficiently be controlled by human judgment, which results in time and cost consuming but can easily be controlled by using DOE techniques. The design of the experiment is expected to gain more accurate answers on system behaviour and interaction effects, especially when created on basis of fractional factorial designs

The present study can be concluded in the following steps:

- Optimum parameters for surface roughness are spindle speed of 1150rpm, feed rate 0.1mm/rev, depth of cut 1.5mm while cutting with TNMG coated insert.
- Optimum parameters for material removal rate are spindle speed of 1150rpm, feed rate 0.15mm/rev, depth of cut 0.75mm while cutting with TNMG coated insert.
- Optimum parameters for surface roughness are spindle speed of 1400rpm, feed rate 0.1mm/rev, depth of cut 1.5mm while cutting with TNMG uncoated insert.

- Optimum parameters for material removal rate are spindle speed of 800rpm, feed rate 0.15mm/rev, depth of cut 1.5mm while cutting with TNMG uncoated insert.

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