Turning Constraints of Aluminium Alloy 7075 using CNMG and VNMG Inserts.

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ABSTRACT

Almost 80% of a viable & Army airframe is made of aluminium alloys. It is predictable that the usage of aluminium alloy is to upsurge up to 70% by the year 2025. They are mainly used because of their high strength to weight ratio. This project presents a study of the cutting tool performance of an CNMG Carbide & VNMG carbide tool in operation on Al 7075, in which the volume of material removed and surface roughness were investigated. The machining tests were conducted on a CNC lathe machine to obtain the MRR and surface roughness of the Aluminium Alloy 7075 work piece material. The average surface roughness (Ra) was measured using a Mitutoyo surface roughness tester. The effect of these cutting constraints on each of these variables was examined, as well as the possible interrelation between them. The experimental results showing that the mechanical effects, produced by the feed, should not be neglected against the thermal effects, produced by the cutting speed, within the range of the tested cutting speed.

1. INTRODUCTION

CNC Metal cutting is one of the mostly used manufacturing process, and its advancement in technology continues to the progress in material science development. The productivity and efficiency of the metal removal processes depends on machining constraints such as cutting conditions, cutting tool geometry as well as the work piece and tool material[(1)]. The main significance of this research is to predict the surface roughness and MRR using Taguchi method during turning of AA7075 by optimizing the constraints like cutting speed, feed rate, & depth of cut in order to achieve good surface roughness. From the literature Survey it is detected that many research used using ANN method to optimize surface roughness.

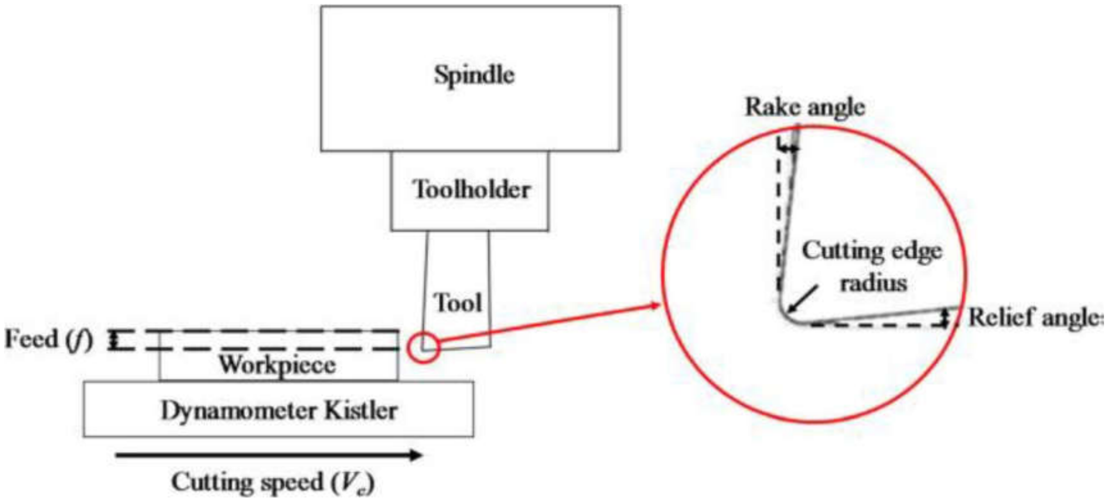


Fig 1. Orthogonal Linear Set up

In this experimental work an alloy of Aluminium Al 7075 which is most usually used in aeronautical and manufacturing industries with vast range has been taken as a material for investigation and the effect of cutting speed, feed and depth of cut on surface roughness using 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, the 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 alloy, turned, was carried out in with this work. The influence of these cutting constraints 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 work piece material used in the machining tests was 25mm x 80 mm Al 7075 round rod. The chemical composition & mechanical properties of the work piece 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

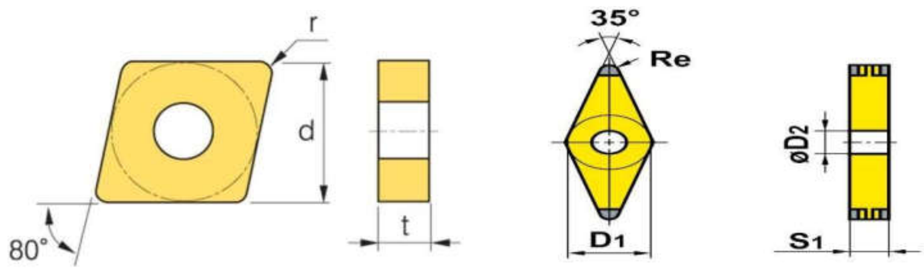
Table: 02

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

A round bars of dia, D = 25 mm; length, L = 80 mm were used to production the specimens. A length of 30 mm was turned as the surface Roughness Measurement. A new tool was used in this last procedure, 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 were,



I. CNMG carbide tool.
II. VNMG 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 alteration (ANOVA) using Taguchi method have been used for optimization of speed, feed rate and depth of cut and to study its properties on surface roughness. The material used for the study is aluminium alloy Al 7075. The machining tests were conducted on SUPER JOBBER 500LM CNC lathe machine and the technical provisions of the machine is 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_25
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 constraints and values used in the experiment are shown in Table 4.

Table: 04

Constraints	**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 weight of turned chip in order to determine the MRR and Time for turning that occurred during the machining operation.

I. Surface Roughness and MRR Analysis for CNMG INSERT.

The optimization of the control factors after performing turning operation were done using Minitab 18 software. The consistent experimental for CNMG plan is as shown in Table 05. The signal to noise ratio (S/N) is a measure in engineering to compare desired signal to background noise. The signal to noise ratio (S/N) for surface roughness values were calculated using smaller-the-better features as per the Taguchi's L27 orthogonal array. The consistent S/N ratio shown as delta is as shown for CNMG 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

CNMG					
EXP NO.	**Spindle Speed**	**Feed Rate**	**Depth of Cut**	**Surface Roughness**	**MRR**
	rpm	**mm/rev**	**Mm**	**μm**	**gm/sec**
C01	800	0.1	0.25	1.74	0.114286
C02	800	0.1	0.75	1.45	0.304762
C03	800	0.1	1.5	1.96	0.457143
C04	800	0.15	0.25	2.53	0.171527
C05	800	0.15	0.75	2.32	0.457404
C06	800	0.15	1.5	2.16	0.686106
C07	800	0.2	0.25	3.28	0.228571
C08	800	0.2	0.75	3.2	0.609524
C09	800	0.2	1.5	3.3	0.990476
C10	1150	0.1	0.25	1.52	0.219058
C11	1150	0.1	0.75	1.64	0.383352
C12	1150	0.1	1.5	1.61	0.711939
C13	1150	0.15	0.25	2.4	0.328677
C14	1150	0.15	0.75	2.25	0.739523
C15	1150	0.15	1.5	3.5	1.0682
C16	1150	0.2	0.25	3.35	0.328587
C17	1150	0.2	0.75	3.31	0.876232
C18	1150	0.2	1.5	3.37	1.314348
C19	1400	0.1	0.25	1.48	0.266667
C20	1400	0.1	0.75	1.89	0.6
C21	1400	0.1	1.5	1.84	0.866667
C22	1400	0.15	0.25	2.33	0.3003
C23	1400	0.15	0.75	2.36	0.800801
C24	1400	0.15	1.5	2.39	1.201201
C25	1400	0.2	0.25	3.28	0.4
C26	1400	0.2	0.75	3.29	1.066667
C27	1400	0.2	1.5	3.39	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 product. The process constraints with the least signal to noise ratio yield the optimal quality with minimum alteration.

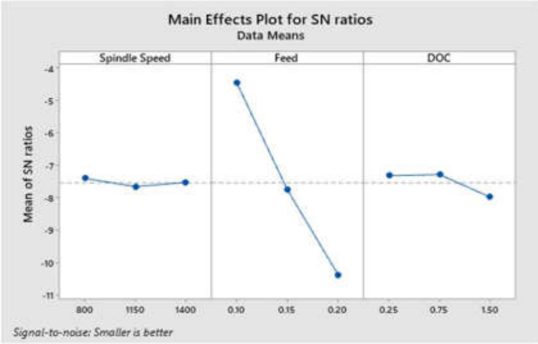


Figure: 03(a)

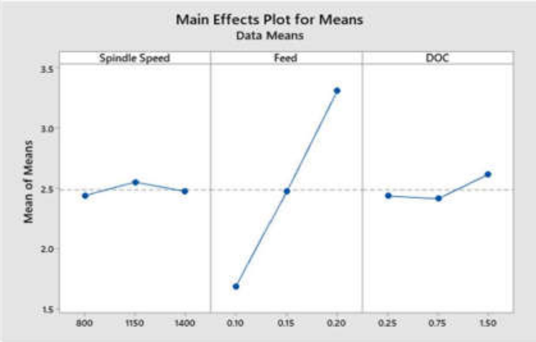


Figure: 03(b)

TABLE: 06

Response Table for Signal to Noise Ratios

Smaller is better

Level	Spindle Speed	Feed	DOC
1	-7.415	-4.465	-7.334
2	-7.672	-7.774	-7.301
3	-7.541	-10.390	-7.994
Delta	0.257	5.925	0.693
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	0.298	0.298	0.1488	0.18	0.836
Feed	2	158.676	158.676	79.3379	96.31	0.000
DOC	2	2.750	2.750	1.3750	1.67	0.214
Residual Error	20	16.476	16.476	0.8238		
Total	26	178.199				

Table 07 shows the analysis of alteration (ANOVA) for S/N ratios of Surface Roughness. From the results of Minitab software it is detected that for turning of aluminium alloy 7075, the spindle speed contributed 0.16% and feed rate and depth of cut contributed 89.04% and 1.54% 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 product. The process constraints with the least signal to noise ratio yield the optimal quality with minimum alteration.

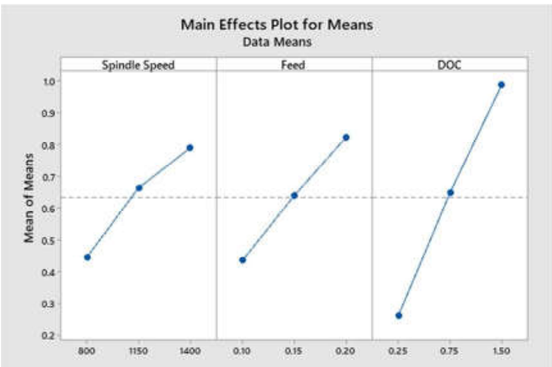


Figure 4(a)

Figure 4(b)

TABLE: 08

Response Table for Signal to Noise Ratios

Larger is better

Level	Spindle Speed	Feed	DOC
1	-8.7269	-8.6209	-12.1535
2	-4.9579	-5.3198	-4.3686
3	-3.4736	-3.2177	-0.6363
Delta	5.2533	5.4033	11.5173
Rank	3	2	1

TABLE: 09

Analysis of Variance for SN ratios

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Spindle Speed	2	132.02	132.02	66.009	98.67	0.000
Feed	2	133.54	133.54	66.768	99.81	0.000
DOC	2	621.55	621.55	310.774	464.56	0.000
Residual Error	20	13.38	13.38	0.669		
Total	26	900.48				

Table 09 shows the analysis of alteration (ANOVA) for S/N ratios of Material Removal Rate. From the results of Minitab software it is detected that for turning of aluminium alloy 7075, the spindle speed contributed 14.66% and feed rate and depth of cut contributed 14.83% and 69.02% respectively. Considering significant interaction effect between spindle speed and Feed Rate.

II. Surface Roughness and MRR Analysis for VNMG INSERT.

The optimization of the control factors after performing turning operation were done using Minitab 18 software. The consistent experimental for VNMG plan is as shown in Table 10. The signal to noise ratio (S/N) is a measure in engineering to compare desired signal to background noise. The signal to noise ratio (S/N) for surface roughness values were calculated using smaller-the-better characteristics as per the Taguchi's L27 orthogonal array. The consistent S/N ratio shown as delta is as shown for VNMG 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

VNMG					
EXP NO.	**Spindle Speed**	**Feed Rate**	**Depth of Cut**	**Surface Roughness**	**MRR**
	rpm	**mm/rev**	**mm**	**µm**	**gm/sec**
V01	800	0.1	0.25	1	0.114286
V02	800	0.1	0.75	1.07	0.304762
V03	800	0.1	1.5	1.04	0.495238
V04	800	0.15	0.25	1.96	0.171527
V05	800	0.15	0.75	1.85	0.343053
V06	800	0.15	1.5	1.83	0.400229
V07	800	0.2	0.25	3.09	0.228571
V08	800	0.2	0.75	3.15	0.457143
V09	800	0.2	1.5	3.21	0.685714
V10	1150	0.1	0.25	1.08	0.164294
V11	1150	0.1	0.75	1.27	0.438116
V12	1150	0.1	1.5	1	0.657174
V13	1150	0.15	0.25	2.09	0.246508
V14	1150	0.15	0.75	2.12	0.575185

V15	1150	0.15	1.5	2.12	0.986031
V16	1150	0.2	0.25	3.34	0.328587
V17	1150	0.2	0.75	3.23	0.547645
V18	1150	0.2	1.5	3.23	1.09529
V19	1400	0.1	0.25	1.03	0.266667
V20	1400	0.1	0.75	1.07	0.466667
V21	1400	0.1	1.5	1.02	0.8
V22	1400	0.15	0.25	2.19	0.3003
V23	1400	0.15	0.75	2.12	0.600601
V24	1400	0.15	1.5	2.12	1.101101
V25	1400	0.2	0.25	3.24	0.4
V26	1400	0.2	0.75	3.2	0.666667
V27	1400	0.2	1.5	3.17	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 product. The process constraints with the least signal to noise ratio yield the optimal quality with minimum alteration.

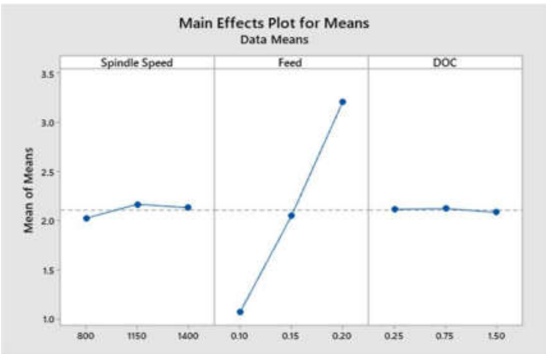


Figure:5(a)

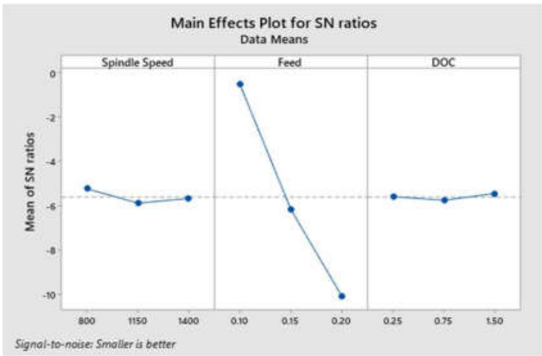


Figure: 5(b)

TABLE: 11

Response Table for Signal to Noise Ratios

Smaller is better

Level	Spindle Speed	Feed	DOC
1	-5.2513	-0.5210	-5.6075
2	-5.8938	-6.1951	-5.7668
3	-5.6904	-10.1193	-5.4612
Delta	0.6425	9.5983	0.3057
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	1.941	1.941	0.971	5.20	0.015
Feed	2	419.163	419.163	209.581	1121.96	0.000
DOC	2	0.421	0.421	0.210	1.13	0.344
Residual Error	20	3.736	3.736	0.187		
Total	26	425.260				

Table 12 shows the analysis of alteration (ANOVA) for S/N ratios of Surface Roughness. From the results of Minitab software it is detected that for turning of aluminium alloy 7075, the spindle speed contributed 0.46% and feed rate and depth of cut contributed 98.56% and 0.09% 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 product. The process constraints with the least signal to noise ratio yield the optimal quality with minimum alteration.

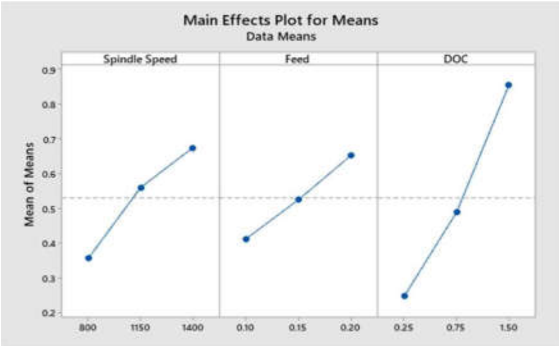


Figure: 6(a)

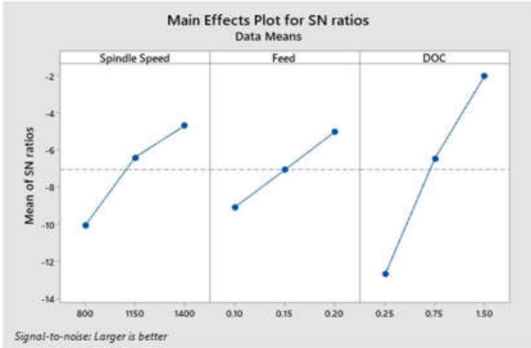


Figure: 6(b)

TABLE: 13

Response Table for Signal to Noise Ratios

Larger is better

Level	Spindle Speed	Feed	DOC
1	-10.080	-9.090	-12.709
2	-6.411	-7.077	-6.465
3	-4.693	-5.017	-2.010
Delta	5.387	4.072	10.699
Rank	2	3	1

TABLE: 14

Analysis of Variance for SN ratios

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Spindle Speed	2	136.32	136.32	68.160	52.43	0.000
Feed	2	74.62	74.62	37.312	28.70	0.000
DOC	2	519.91	519.91	259.957	199.95	0.000
Residual Error	20	26.00	26.00	1.300		
Total	26	756.86				

Table 14 shows the analysis of alteration (ANOVA) for S/N ratios of Material Removal Rate. From the results of Minitab software it is detected that for turning of aluminium alloy 7075, the spindle speed contributed 18.01% and feed rate and depth of cut contributed 9.85% and 68.69% 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 to carry out the complete analysis. First, the normal approach, where the results of a single run, or the average of repetitive runs, are processed through main effect and ANNOVA analyses as identified above. The second approach, which he strongly suggested for multiple runs, is to use signal ratio (S/N) for the same steps in analysis.

Signal-to-Noise ratio is also one more influence of Taguchi. It was developed as a proactive equivalent to the reactive loss function. The signal to noise ratio measures how the response varies relative to the nominal or target value under different noise conditions. Minitab software help to calculate S/N ratio based on required response and provide response table and response plot for determining 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 desired, such as weld strength, gasoline mileage, or yield. From a mathematical view point, the target value is 00, like the loss function. It is the reciprocal of smaller-the-better. The equation is:

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

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 smaller-the-better ratio is:

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

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 constraints such as spindle speed, feed rate and depth of cut. The optimization of the process has been performed using analysis of alteration (ANOVA). Based on this research work, the following results have been drawn.

1. While Cutting with CNMG insert, for lower cutting speeds, as the cutting speed decreases, the surface roughness values decrease. Also, for higher feed rates the surface roughness values changes considerably
2. While Cutting with CNMG insert, for lower cutting speeds, as the cutting speed increases, the Material Removal Rate values also increases. Also, for higher feed rates the surface roughness values changes considerably.
3. While Cutting with VNMG insert, for lower cutting speeds, as the cutting speed decreases, the surface roughness values decrease. Also, for higher feed rates the surface roughness values changes considerably but At around 1000 rpm we get good Surface roughness.
4. While Cutting with VNMG insert, for lower cutting speeds, as the cutting speed increases, the Material Removal Rate values also increases. Also, for higher feed rates the surface roughness values changes considerably.
5. This method of optimization of surface roughness in turning of Al 7075 techniques using Taguchi method can be further studied for different materials.

6. Conclusion

This study presented an efficient method for determining the optimal turning operation constraints for 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 constraints, and a response variable of surface roughness and MRR. For the research L27 orthogonal array was used with five control restraints. The study found that the control factors had varying effects on the response variable, cutting condition are not significant for material removal rate but significant for surface roughness; dry cutting is better than wet cutting situation. Spindle speed and depth of cut is less significant parameter for both MRR and Surface roughness in both condition. Feed rate is more momentous parameter following tool nose radius for the surface roughness. Tool nose radius is more significant parameter following for 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. Design of experiment is expected to gain more accurate answers on system behaviour and interaction effects, particularly when created on basis of fractional factorial designs

The present study can be concluded in the following steps:

- Optimal restraints for surface roughness are spindle speed of 800rpm, feed rate 0.1mm/rev, depth of cut 0.75mm while cutting with CNMG insert.
- Optimal restraints for material removal rate are spindle speed of 800rpm, feed rate 0.1mm/rev, depth of cut 0.25mm while cutting with CNMG insert.
- Optimal restraints for surface roughness are spindle speed of 1150rpm, feed rate 0.1mm/rev, depth of cut 1.5mm while cutting with VNMG insert.
- Optimal restraints for material removal rate are spindle speed of 800rpm, feed rate 0.1mm/rev, depth of cut 0.25mm while cutting with VNMG insert.

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