Optimization of Cutting Parameters in Turning Operation of Aluminium 7075 Alloy

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***Abstract*-Surface finish is one of the prime requirements of customers for mechanical parts. This research paper is focused on the analysis of optimum cutting conditions to get lowest surface roughness in turning by regression analysis. An experimental study was carried out to investigate the effect of cutting parameters like spindle speed, feed and depth of cut on surface finish in turning on Aluminum 7075 alloy. A multiple regression analysis (Ra) using analysis of variance is conducted to determine the performance of experimental measurements and to it show the effect of cutting parameters on the surface roughness. Multiple regression modeling was performed to predict the surface roughness by using machining parameters. Machining was done by using tungsten carbide tool. The objective was to establish correlation between cutting speed, feed rate and depth of cut and optimum the turning conditions based on surface roughness. These correlations are obtained by multiple regression analysis (RA).**

Keywords: Machining, Surface Roughness, Orthogonal Array, Regression Analysis.

I. INTRODUCTION

Turning is a machining process in which a cutting tool, typically a non –rotary tool bit, describes a helical tool path by moving more or less linearly while the work piece rotates. The tool axes of movement may literally a straight line, or they may be along some set of curves or angles, but they are essentially linear (in the non mathematical sense). Usually the term “turning” is reserved for the generation of external surfaces by this cutting action, where as this same essential cutting action when applied to internal surfaces (that is, holes, of one kind or another) is called “boring”. Thus the phrase “turning and boring” categorizes the large family of (essentially similar) processes. The cutting of faces on the work piece (that is, surfaces perpendicular to its rotating axis). Whether with a turning or boring tool, is called “facing”, and may be lumped into either category as a subset. Turning can be done manually, in traditional form of lathe, which frequently requires continuous supervision by the operator, or by using an automated lathe which does not. Today the most common type of such automation is computer numerical control, better known as CNC. (CNC is also commonly used with any other types of machining besides turning).

Taguchi methods developed by Genichi Taguchi improve the quality of manufacturing roots are recently applied to the field of engineering, biotechnology, marketing and advertising. The Taguchi method is a very powerful carrying of experimental design, the main aim of the Taguchi methods is to produce an optimum result of analyzing the statistical data which have been given as input function. This method allows limited no of experimental runs by utilizing a well balanced experimental design called orthogonal array design and signal to noise ratio.

Surface roughness has received serious attention for many years. It has formulated an important design feature in many situations such as parts subject to fatigue loads, precision fits, fastener holes and requirements. In addition to tolerances, surface roughness imposes one of the main critical constraints for the selection of machines and cutting parameters in process planning. Surface finish is the method of measuring the quality of a product and important parameter in machining process. It is one of the prime requirements of customers for machine parts.

2. EXPERIMENTAL DETAILS

The experiments for conducted specimens of the size of 20 mm diameter work pieces were machined from Aluminum 7075 alloy. The cutting parameters are shown in table 3. The levels of cutting speed, three levels of feed, three levels of depth of cut for used are shown in table 3. The L9 orthogonal array is selected as per standard suggested Taguchi approach. The base materials chemical composition is given in the table 1.

Table 1: Base material AL 7075 chemical composition

Zn	Mg	Cu	Others
5.6-6.1	2.1-2.5	1.2-1.6	<0.5

Fig1: Turning process

Fig2: Aluminum 7075 work pieces

3. OPTIMIZTION OF SURFACE FINISH

3.1 Selection of parameters and levels

The surface roughness was measured by using CNC lathe instrument. The dependent variable is surface roughness. The total 9 experiments were conducted and responses are shown in the table. It gives the various cutting parameters for each experiment the results are measured and shown in the last column of the same table. The different units used here are cutting speed (rpm), feed (mm/rev), depth of cut (mm), surface roughness and material removal rate (mm^3/min). Minitab software was used for Regression analysis.

3.2 Selection of Orthogonal Array

Based on the number of factors and levels are suitable Taguchi orthogonal array for the experiments selected by using MINITAB17 statistical software. There are three factors having three levels each, L9 orthogonal array chosen..

Table 2: Process parameters levels

S.No.	Cutting parameters	Level 1	Level 2	Level 3
1	Cutting speed(rpm)	2000	3000	5500
2	Feed(mm/rev)	250	500	750
3	Depth of cut(mm)	0.8	0.9	1

3.3 Experimental Procedure

Taguchi analysis is performed according to the selected design of experiment table. The maximum material removal rate and minimum surface finish developed in each set of combinations are noted and tabulated in table. For each experiment the orthogonal array, signal to noise(S/N) ratio are calculated. The quality response is mainly divided into three main types; the larger is better (LTB), the smaller is better (STB) and the nominal is better (NTB).

Smaller-the-better' S/N=-10*log ($\sum(Y^2)$/n)

'Nominal-the-better' S/N=-10*log (s^2)

'Larger-the-better' S/N=-10*log ($\sum$ ($1/Y^2$)/n)

Where Y is the calculated average and s is the standard deviation. Where n denotes number of measurements. The S/N ratio is calculated based on LTB criterion and tabulated in the table. The S/N ratio is calculated based on STB criterion and tabulated in the table. From the below table smaller is better for surface finish and larger is better for material removal rate.

$$S/N=-10*\log(\sum(Y^2)/n)$$

$$S/N=-10*\log(\sum(1/Y^2)/n)$$

From the below signal to noise ratios of each level of factor it is concluded that the optimum factor level to achieve optimum surface finish is 1.05. which are having maximum s/n ratios i.e., speed at 2000rpm, feed at 750mm/rev and depth of cut is 1mm. optimum factor level to achieve optimum material removal rate is 240500mm^3/min. which are having maximum s/n ratios i.e., speed at 5500rpm, feed at 750mm/rev and depth of cut is 0.8mm.

Table 3: experimental results for surface finish, material removal rate corresponding s/n ratios of cutting parameters

S.No.	Speed	Feed	Depth of cut	Surface finish	S/N ratio	MRR	S/N ratio
1	2000	250	0.8	1.61	-4.1	34400	90.7
2	2000	500	0.9	1.14	-1.1	96590	99.6
3	2000	750	1	1.05	-0.4	154810	103.7
4	3000	250	0.8	1.23	-1.7	68320	96.6
5	3000	500	0.9	1.2	-1.5	128350	102.1
6	3000	750	1	1.18	-1.4	198000	105.9
7	5500	250	0.8	1.42	-3	105000	100.4
8	5500	500	0.9	1.35	-2.6	184200	105.3
9	5500	750	1	1.31	-2.3	240500	107.6

Table 4: Response Table for Signal to Noise Ratios Smaller is better

Level	Speed	Feed	Depth of cut
1	-1.899	-2.993	-2.727
2	-1.606	-1.776	-1.761
3	-2.666	-1.402	-1.684
Delta	1.06	1.591	1.043
Rank	2	1	3

From the delta values it assigns the rank to each factor which is having more influence on the mean of surface finish. From the results of S/N ratio also it is observed that feed is the dominant factor for surface finish.

Table 5: Response Table for Signal to Noise Ratio Larger is better

Level	Speed	Feed	Depth of cut
1	98.08	95.95	100.66
2	101.6	102.39	101.34
3	104.45	105.78	102.13
Delta	6.38	9.84	1.47
Rank	2	1	3

From the delta values it assigns the rank to each factor which are having more influence on the man of material removal rate, from the results of S/N ratio also it is observed that tool traverse feed is the dominant factor for material removal rate distribution.

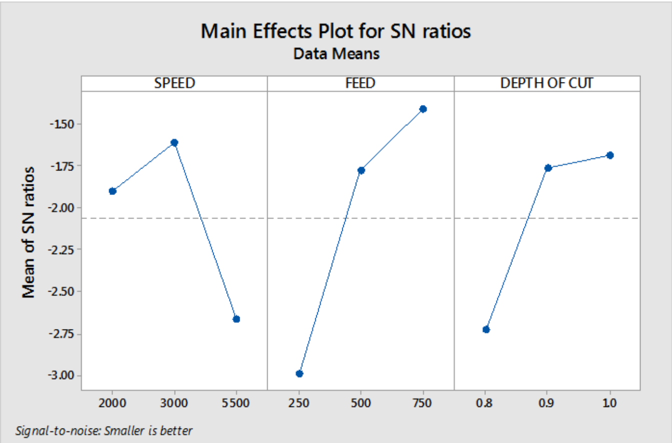

Fig 3: Graphical results for Surface finish

Based on the above graph, the optimum conditions for the surface finish are (a): 2000rpm speed (b): 750mm/min feed (c): 1mm depth of cut.

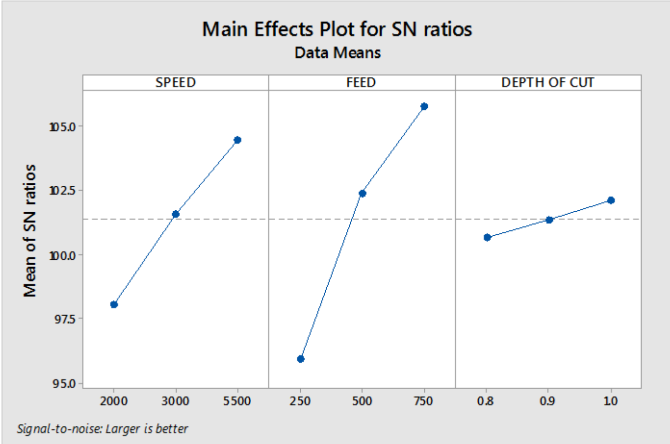

Fig 4: Graphical results for Material Removal Rate

Based on the above graph, the optimum conditions for the material removal rate are (a): 5500rpm speed (b): 750mm/min feed (c): 1mm depth of cut.

REGRESSION ANALYSIS (RA)

It s used to investigate and model the relationship between a response variable and one or more predictors. Minitab provides least square, partial least square and logistic regression procedures. A multiple regression analysis was conducted on the tested data. Coefficients of the analysis of the regression model also supported linear relationships in the model.

SURFACE FINISH=2.104+0.000034 SPEED-0.

000480 FEED- 0.783 DEPTH OF CUT

Table 6: Coefficient of analysis

Term	Coef	SE Coef	T-value	P-value	VIF
Constant	2.104	0.490	4.30	0.008	
Speed	0.000034	0.000029	1.17	0.295	1.00
Feed	-0.000480	0.000207	-2.32	0.068	1.00
Depth of cut	-0.783	0.518	-1.51	0.191	1.00

S=0.126793 R-sq=64.37% R-sq (adj)=42.99% R-sq(pred)=0.00%

Table 7: Analysis of variance

Source	DF	Adj SS	Adj MS	f-value	p-value
Regression	3	0.014522	0.04841	3.01	0.133
Speed	1	0.02200	0.02200	1.37	0.295
Feed	1	0.08640	0.08640	5.37	0.068
Depth of cut	1	0.03682	0.03682	2.29	0.191
Error	5	0.08038	0.01608		
Total	8	0.22560			

Table 8: Fits and Diagnostics for Unusual Observations

Obs	Surface finish	Fit	Resid	Std resid
1	1.6100	1.4246	0.1845	2.20R

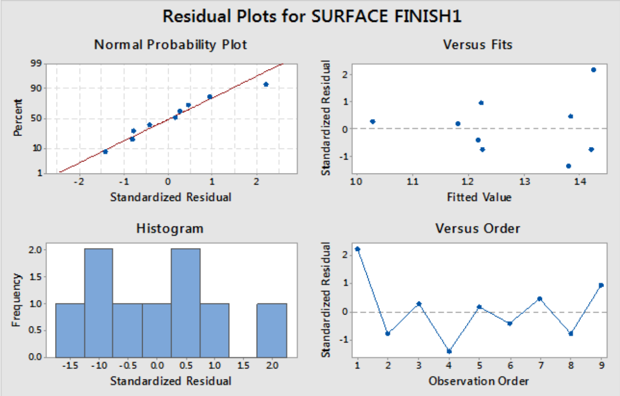

Fig 5: Residual plots for surface roughness

Regression equation is

MRR= -29199+22.22 SPEED+257.1FEED-47400DEPTH OF CUT

Table 9: Coefficient of analysis

Term	Coef	SE Coef	T-value	P-value	VIF
Constant	-29199	32291	-0.9	0.407	
Speed	22.22	1.89	11.73	0.000	1.00
Feed	257.1	13.7	18.82	0.000	1.00
Depth of cut	-47400	34145	-1.39	0.224	1.00

Table 10: Analysis of variance

Source	DF	ADJ SS	ADJ MS	F-value	P-value
Regression	3	3.45E+008	1.15E+008	164.62	0.000
Speed	1	9.63E+007	9.63E+007	137.68	0.000
Feed	1	2.47E+008	2.47E+008	354.26	0.000
Depth of cut	1	1.34E+006	1.34E+006	1.93	0.224
Error	5	3.49E+006	6.99E+005		
Total	8	3.48E+008			

S=8363.84 R-sq=99.00% R-sq=98.40% R-sq=96.66%

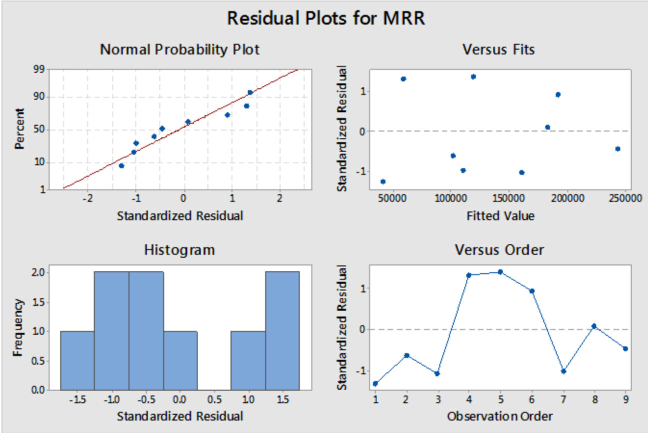

Fig 6: Residual plots for material removal rate

Table 11: Predicted values of surface finish and material removal rate

S.no	Speed (rpm)	Feed (mm/rev)	Depth of cut (mm)	Surface finish	MRR (mm^3/min)
1	2000	250	0.8	1.4256	41596
2	2000	500	0.9	1.2273	101131
3	2000	750	1	1.029	160666
4	2000	250	0.9	1.3473	36856
5	2000	500	1	1.149	96391
6	2000	750	0.8	1.1856	170146
7	2000	250	1	1.269	32116
8	2000	500	0.8	1.3056	105871
9	2000	750	0.9	1.1073	165406
10	3000	250	0.8	1.4596	63816
11	3000	500	0.9	1.2613	123351
12	3000	750	1	1.063	182886
13	3000	250	0.9	1.3813	59076
14	3000	500	1	1.183	118611
15	3000	750	0.8	1.2196	192366
16	3000	250	1	1.303	54336
17	3000	500	0.8	1.3396	128091
18	3000	750	0.9	1.1413	187626
19	5500	250	0.8	1.5446	119366
20	5500	500	0.9	1.3463	178901
21	5500	750	1	1.148	238436
22	5500	250	0.9	1.4663	114626
23	5500	500	1	1.268	174161
24	5500	750	0.8	1.3046	247916
25	5500	250	1	1.388	109886
26	5500	500	0.8	1.4246	183641
27	5500	750	0.9	1.2263	243176

Comparing experimental values and Predicted values surface finish is better at the levels of (a):2000rpm speed (b):750mm/rev feed (c):1mm depth of cut and material removal rate is at (a):5500 rpm speed (b): 750 mm/rev

(c): 0.9mm depth of cut.

By using cutting forces Stress and Displacements are designed in ANSYS:

Cutting Force

Ne = (Depth * Feed*Cutting speed*Ks) / $(60*10^3$*Coefficient of Efficiency)

Ne = 4.65KW

Ks = (Ne*60*103*Coefficient of efficiency) / (Depth of cut * Feed* Cutting speed)

Coefficient of efficiency = 0.8

Ks = (4.65*60*103*0.8) / (0.8*250*2000)

Ks = 558N

Feed = 500mm/min, Depth of cut = 0.9mm

Ks = (4.65*60*103*0.8) / (0.9*500*2000)

Ks = 248N

Feed = 750mm/min, Depth of cut = 1mm

Ks = (4.65*60*103*0.8) / (1*750*2000)

Ks = 148.8N

Table 12: Cutting forced by using input parameters

S.no	Speed(rpm)	Feed(mm/min)	Depth of cut(mm)	Cutting forces(N)
1	2000	250	0.8	558
2	2000	500	0.9	248
3	2000	750	1	148.8
4	3000	250	0.9	330.66
5	3000	500	1	148.8
6	3000	750	0.8	124
7	5500	250	1	162.32
8	5500	500	0.8	101.45
9	5500	750	0.9	60.12

STRUCTURAL ANALYSIS OF CUTTING FORCES – 558N

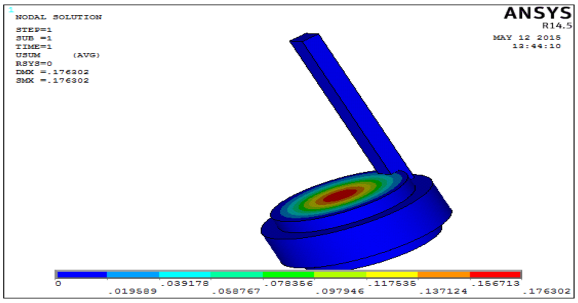

Fig 7: Displacement vector produced by cutting forces 558N

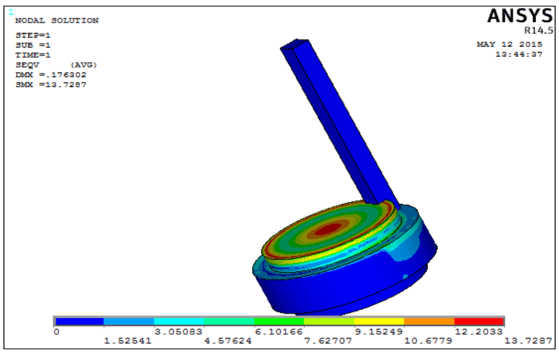

Fig 8: Vonmises Stress produce by cutting force 558N

Table 13: Structural Analysis results of cutting forces

S.no	Force(N)	Displacement(mm)	Stress(N/mm^2)
1	558	0.176302	13.7287
2	248	0.078128	6.1041
3	148.8	0.046896	3.66312
4	330.66	0.104618	8.14033
5	148.8	0.046896	3.66312
6	124	0.039226	3.05278
7	162.32	0.05116	3.996
8	101.45	0.032413	2.4984
9	60.12	0.019211	1.48056

DYNAMIC ANALYSIS OF CUTTING FORCE -330.66N at 10 sec

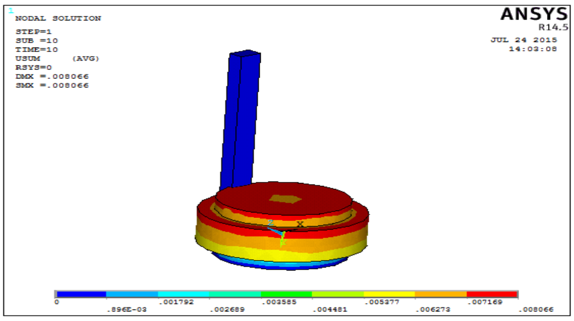

Fig 9: Displacement vector produced by cutting force 330.66N at 10 sec

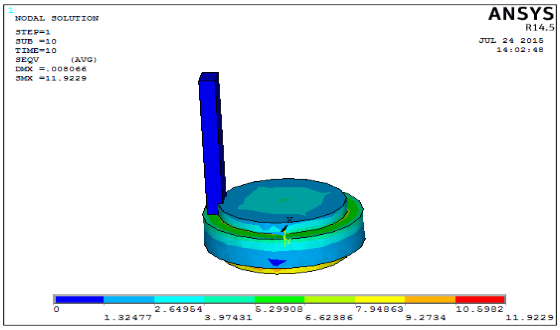

Fig 10: vonmises Stress by cutting force 330.66N at 10 sec

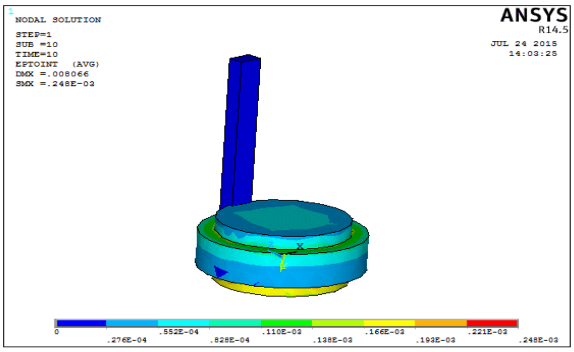

Fig11: Vonmises Strain produced by Cutting force 330.66N at 10 sec

Table 14: Dynamic analysis results of cutting forces

S.no	Force (N)	Time (sec)	Displacement(mm)	Stress (N/mm^2)	Strain
1	558	10	0.249414	21.5765	0.01498
2	558	20	0.1292	22.5287	0.01563
3	558	30	0.13466	23.481	0.01633
4	330.66	10	0.008066	11.9229	0.01234
5	330.66	20	0.008602	12.718	0.008862
6	330.66	30	0.008962	13.2481	0.00921
7	162.32	10	0.00272	4.75952	0.016233
8	162.32	20	0.003639	6.3461	0.01620
9	162.32	30	0.004367	7.6154	0.005277

CONCLUSION

Experiments were done to optimize cutting parameters during turning of Aluminum 7075 alloy using tungsten carbide cutting tool. The cutting parameters are cutting speed, feed and depth of cut. The following conclusions were drawn from the present investigation.

1. The tool traverse feed observed to have more influence on the mean of surface finish and mean of material removal rate.

2. The speed at 2000 rpm, feed at 750mm/rev and depth of cut at 1 mm were observed to have good minimum surface finish.

3. The speed at 5500 rpm, feed at 750 mm/rev and depth of cut 0.9mm were observed to give maximum material removal rate.

4. The effects of these parameters on the cutting forced were calculated using theoretical calculations and stresses and displacements were analyzed by using cutting forces through ANSYS. From the total analysis the stress values for observed to be less than the yield stress values.

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