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Optimization of Cutting Parameters in Turning Operation of AA2014-T4 Aluminum Alloy

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ABSTRACT

AA2014-T4 Aluminum alloy is wide application in aeronautics they are formed in required shape by machining process. In this experiment the effects of the machining parameters cutting speed (Vc), the feed rate (f) and depth of cut (d) on main cutting force (Fc), and surface roughness (Ra) is investigated. The effects of the cutting parameters on cutting force and surface roughness has been examined by the use of Variance Analysis (ANOVA). There are many factors that affect the performance of cutting tool especially when dry machining, cutting tool is one of that. We try to investigate the optimum cutting parameter for coated carbide cutting tool for dry machining Aluminum Alloy in terms of cutting force, and surface finish. From this study, the result shows that optimum condition for selected cutting inserts are ($V_c = 140\ m/min\ \ f = 0.1m/\ min\ d = 0.5mm$). Optimum cutting force & surface roughness for coated tool is 117.9 N, 0.83µm respectively

Keywords: Annova ,AA2014-t4 ,cutting force,), s/n ratio, surface roughness, taguchi

I. INTRODUCTION

Machining is most widal manufacturing process in mechanical manufacturing industry. Al-Cu alloys are one of the indispensable materials of the current industry because of their superior properties over other metal alloys. They can also undergo aging heat treatment which engenders them to be widely used in the industry. Because of its high mechanical performance and its low density 2014- T2 alloy is used in the aircraft industry for numerous applications such as fuselage and door skin, dorsal pin and trailing edge, panel. [1]

AA2014 alloy, as an Al-Cu alloy, is generally shaped by using machining methods. Many problems such as health and environment issues are identified with the use of cutting fluids in machining processes. For economic as well as environmental reasons machining process is carried out without any cutting fluid but dry machining has some disadvantages. During dry machining process, temperature of the cutting tool is very high and this induces excessive tool wear thus decreasing tool life. The problems of cutting fluid contamination and disposal are not seen in dry machining. Tool rigidity and surface topology, cutting speed, feed rate, depth of cut and tool geometry are also important factors for the determining of ideal machinability behaviours in addition to mechanical properties of a work piece. Turning is machining operation which is done on the CNC lathe. The quality of machined surface and lower cutting force less cutting tool wear (BLU/BLE) is response parameter machiniability point of view. The quality of surface finish and cutting force plays very important role in dry

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turning. The experiments are designed & parameter is analyzed by the application of taguchi analysis. Finally optimize the responses parameter by application of multi-response optimization technique GRA (Grey relational analysis)

II. EXPERIMENTAL SETUP AND METHODS

The experiment has been conducted in CNC turning on AA2014-T4 aluminium alloy using coated carbide inserts. The focus of this work is on effect of speed, feed and depth of cut and coating on cutting force and surface roughness

2.1 Machine tool :-

Fig 1- Retrofitted VDF Lathe

2.2 Dynamometer for Force Measurement:-Kistler dynamometer are used to measure the cutting force during turning operation .the multi component dynamometer provide dynamic measurement of three component of force. Kistler make Four-component piezo-electric dynamometer is used to measure the cutting forces. This dynamometer can be used for measuring torque (Mz) and the three orthogonal components of a force (Fx,Fy,Fz). The dynamometer has a great rigidity and consequently a high natural frequency.

2.3 Work Material: - The work material used in test is aeronautics aluminium alloy AA2014-T4.the dimension of work piece is 40mm diameter and 400mm length. The composition and properties are given in table

Table 2.1 COMPOSITIONS IN WT %

Ti	Si	Fe	Cu	Mn	Mg	Zn	Al
0.15	0.672	0.512	4.33	0.564	0.401	0.168	Balance

2.4 Cutting Tools and Specifications

Cutting inserts used in performing turning test coated carbide inserts that are wedia CNMG120408MC-TT1500.

2.5 Experiment Procedure

1. Design experiment with different parameter.
2. Conduct experiment as per full factorial random order.
3. Measure cutting force by Kistler dynamometer.
4. Measure surface roughness by handy surf.

Experiment was conducted with single point cutting tool on CNC turning machine, as per L27 orthogonal array.

Process Variables and Their Limits-The working ranges of the parameters for subsequent design of experiment, based on Taguchi's L27 Orthogonal Array (OA) design have been selected. In the present

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experimental study, spindle speed, feed rate and depth of cut have been considered as process variables. The process variables with their units (and notations) are listed in

Table 2.2 Process Variables and Their Limits

Symbol	Parameter	Level 1	Level 2	Level 3
v	Cutting speed (m/min)	80	110	140
f	Feed rate (mm/rev)	0.1	0.2	0.3
d	Depth of cut (mm)	0.5	1.0	1.5

III. RESULT AND DESCUUSION

3.1 Observations Table:-On CNC machine performs turning operation and recorded responses parameter (cutting force & surface roughness) with all 27 set of experiment (design by Taguchi method) for coated inserts-

Table 3.1 Record of Cutting Force and Surface Roughness

	Cutting Parameter			Response Parametrer	
Sr	Vc(m/min)	F(mm/rev)	D(mm)	Ra(µm)	Fc(N)
1	80	0.1	0.5	1.34	125.6
2	80	0.1	1	1.93	163
3	80	0.1	1.5	1.98	209
4	80	0.2	0.5	1.86	135
5	80	0.2	1	2.3	140
6	80	0.2	1.5	2.46	211.1
7	80	0.3	0.5	2.43	131.3
8	80	0.3	1	2.49	165.7
9	80	0.3	1.5	2.58	228.6
10	110	0.1	0.5	1.04	117.2
11	110	0.1	1	1.7	159.2
12	110	0.1	1.5	1.81	200.3
13	110	0.2	0.5	1.56	125.5
14	110	0.2	1	2.17	165.8
15	110	0.2	1.5	2.36	209.1
16	110	0.3	0.5	2.23	122.3
17	110	0.3	1	2.29	155.5
18	110	0.3	1.5	2.34	214.5
19	140	0.1	0.5	0.83	117.3
20	140	0.1	1	1.6	157.3
21	140	0.1	1.5	1.68	193.5
22	140	0.2	0.5	1.35	111.6
23	140	0.2	1	1.91	168.7

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24	140	0.2	1.5	2.09	204.3
25	140	0.3	0.5	2.12	109.6
26	140	0.3	1	2.17	143.8
27	140	0.3	1.5	2.24	199.3

3.2 Taguchi Analysis -Minitab-16 software has been used for taguchi analysis of results

3.2.1 Taguchi Analysis: Fz(N) versus Vc(m/min), f (mm/rev), d (mm)

Table 3.2 Analysis of Variance for Means

Source	DF	Seq SS	Adj SS	Adj MS	F	P	% contri
Vc(m/min)	2	1217	1217	608.5	18.37	0.001	3.465
f (mm/rev)	2	4755.3	4755.3	2377.7	71.78	0	13.540
d (mm)	2	28137.8	28137.8	14068.9	424.74	0	80.121
Vc(m/min)*f (mm/rev)	4	516.5	516.5	129.1	3.9	0.048	1.471
Vc(m/min)*d (mm)	4	30.1	30.1	7.5	0.23	0.916	0.085
f (mm/rev)*d (mm)	4	197.3	197.3	49.3	1.49	0.292	0.561
Residual Error	8	265	265	33.1			0.744
Total	26	35119					

S = 5.755 R-Sq = 99.2% R-Sq(adj) = 97.5%

P value shows that machining with coated insert while measuring cutting force only depth of cut, feed and cutting speed are significant. There is no significance of interaction of cutting parameter except Vc (m/min)*f (mm/rev). The percentage contribution of depth of cut is 80.121% feed rate 13.54%, cutting force 3.465%

Increasing cutting force with depth of cut with interaction of feed and cutting speed is increasing linear. Cutting force increases with feed in curved form, for all values of cutting speed and depth of cut. Increasing cutting speed, cutting force decreases slightly.

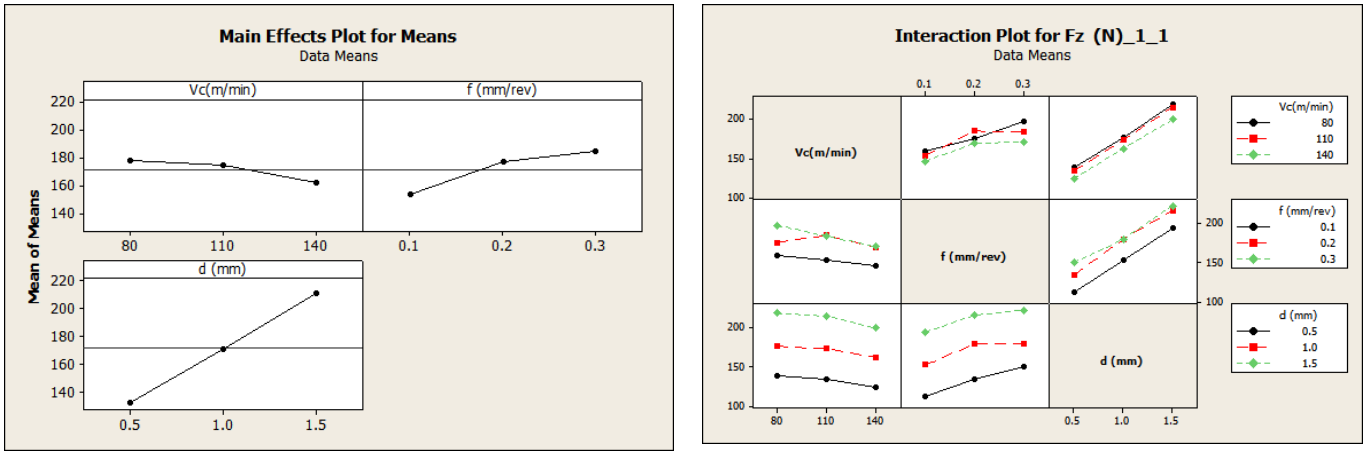

Fig 2– Main Effect Plot for Cutting Force and Interaction Plot for Cutting Force

3.2.2 Taguchi Analysis: Ra versus Vc(m/min), f (mm/rev), d (mm)

Variance analysis shows that cutting speed, feed, depth of cut and feed*depth of cut are significant factor for surface roughness. Percentage contribution of feed over surface finish is maximum 51.05% then depth of cut 27.09% , cutting speed 11.22% and interaction of feed*depth of cut are 9.26%.

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Table 3.2 Analysis of Variance for Means

Source	DF	Seq SS	Adj SS	Adj MS	F	P	% contri.
Vc(m/min)	2	0.63562	0.63562	0.31781	125.04	0	11.229
f (mm/rev)	2	2.88976	2.88976	1.44488	568.48	0	51.053
d (mm)	2	1.53342	1.53342	0.76671	301.66	0	27.091
Vc(m/min)*f (mm/rev)	4	0.03116	0.03116	0.00779	3.06	0.083	0.551
Vc(m/min)*d (mm)	4	0.02549	0.02549	0.00637	2.51	0.125	0.450
f (mm/rev)*d (mm)	4	0.52449	0.52449	0.13112	51.59	0	9.266
Residual Error	8	0.02033	0.02033	0.00254			0.359
Total	26	5.66027					

S = 0.05041 R-Sq = 99.6% R-Sq(adj) = 98.8%

Variance analysis shows that cutting speed, feed, depth of cut and feed*depth of cut are significant factor for surface roughness. Percentage contribution of feed over surface finish is maximum 51.05% then depth of cut 27.09% , cutting speed 11.22% and interaction of feed*depth of cut are 9.26%.

Interaction plot show that increasing cutting speed surface roughness decreasing with feed increasing and depth of cut increasing. Main factor affect of surface roughness is feed rate for lower depth of cut and lower cutting speed it is linear but any other level it not fallow linear pattern.

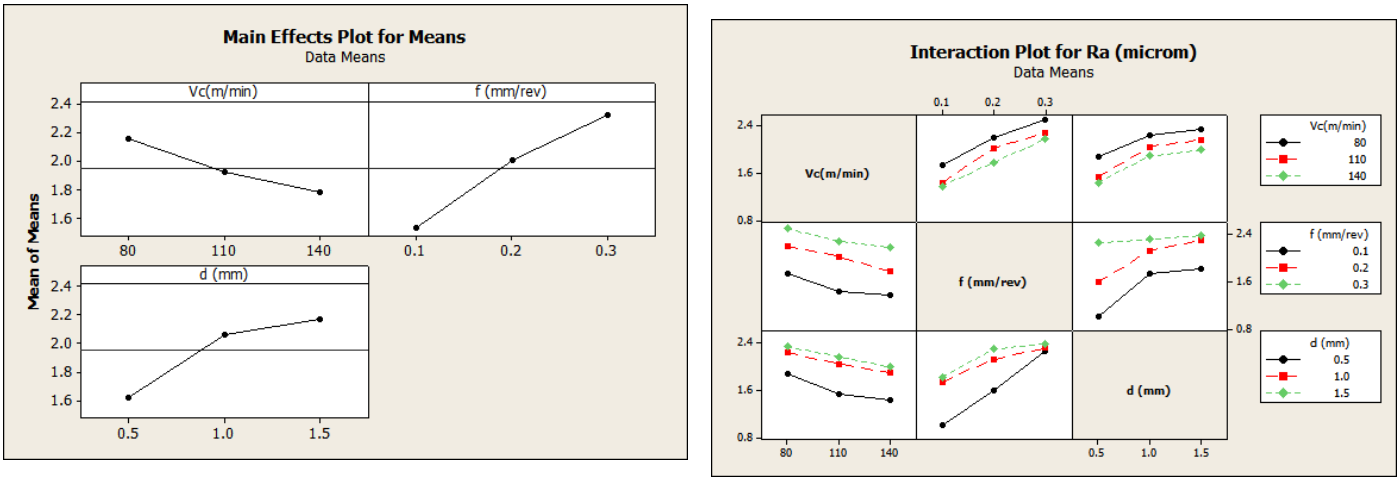

Fig 3 – Main Effect Plot for Surface Roughness and Interaction Plot for Surface Roughness

3.3 Verification of Optimum Condition

Predictive Equation and Verification

The predicted values of Fz and Ra at the optimal levels are calculated by using the relation:

$$\check{n} = nm + \sum_{i=1}^{o} (nim - nm)$$

Where,

ň - Predicted response value after optimization,

nm – Total mean value of quality characteristic,

nim – Mean value of quality characteristic at optimum level of each parameter and

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O – Number of main machining parameters that affect the response parameter

According to taguchi analysis the optimum condition are same for both tool that is speed at 3rd level ,feed rate 1st level and depth of 1st level .verification is done based on GRA analysis.

Table 3.3 Mean Value of Quality Characteristic at Optimum Level of Each Parameter

Parameter	Level	For coated inserts	
		nim of cutting force	nim for Ra
cutting speed	140	153.92	1.82
feed rate	0.1	159.16	1.43
depth of cut	0.5	120.6	1.62

Table 3.4 Total Mean Value of Quality Characteristic

nm of cutting force	nm for Ra
162	1.96

Predicted cutting force for uncoated insert

$$\hat{n} = (nm) + \sum_{i=1}^{o} (nim + nm)$$

$$\hat{n} = (200.51) + [(193.57 - 200.51) + (194.6 - 200.51) + (136.53 - 200.51)]$$

$$\hat{n} = (123.69)$$

Table 3.5 Percentage Error Calculation Between Predicted and Experiment

	Force(N)	Ra(µm)
Predicted	109.68	0.95
Experiment Values	107.3	0.86
Percentage Error	2.16%	9.47%

The values are predicted by GRA approach and find error with actual experimental calculated values .all error are less than, hence it is conform that good reproducibility of results. Result show that for both tool optimum conditions are V3-F1-D1

Table 3.6 Optimum Value of Machining and Response Parameter

CP	OV	POV	EOV	OR
CS	140	Fz=109.68	Fz=107.3	107.3<Fz>109.68
F	0.1	Ra=0.95	Ra=0.86	0.86<Ra>0.95
D	0.5			

CP- cutting parameter

OV- optimum value of parameter

OL-optimum level of parameter

POV-predicted optimum values

EOV-experimental optimum values

OR- optimum range of cutting force and surface roughness

The optimum range of cutting force is 107.3N to 109.68 N and surface finish 0.89-0.95 µm.

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IV. CONCLUSIONS

In this experiment effect of cutting parameter on dry turning of aeronautic aluminium alloy AA2014-T4 has been studied extensively conducting full factorial L27 experiment. Effect of cutting parameter is also investigated in dry machining .the following are the conclusions of the experimental works-

- The basic machining characteristics of machining of AA2014-T4 alloy is for cutting inserts cutting force increases with depth of cut and feed decrease with velocity. Surface roughness increases with feed and depth of cut and decreases with velocity.
- The minimum cutting force obtain at V3f3D1 i.e. cutting speed at level 3-140m/s, feed at level 3-0.3 mm/rev and depth of cut at level 1-0.5 mm is 109.6N
- The minimum surface roughness obtain at V3f1D1 i.e. cutting speed at level 3-140m/s, feed at level 1-0.1 mm/rev and depth of cut at level 1-0.5 mm is 0.83µm
- Optimum condition for selected cutting inserts are V3f1D1 i.e. cutting speed at level 3- 140m/s feed at level 1-0.1 mm/rev and depth of cut at level 1-0.5 mm cutting force & surface roughness for cutting tool is 117.9 N, 0.83µm respectively

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