OPTIMIZATION OF MACHINING PARAMETERS AFFECTING SURFACE ROUGHNESS OF Al6082 IN DRY END MILLING OPERATION ON VMC

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Abstract - *Every manufacturing industry wants to reduce the manufacturing cost and increase the quality of a product. The aim of this project work is to optimize the selected control factors in order to reduce surface roughness in dry end milling operation. In this project Taguchi method is used to determine the optimum machining parameters more efficiently. The cutting parameters are spindle speed, feed rate and depth of cut. These parameters are investigated at three different levels. On the basis of L_{27} orthogonal array of Taguchi method 27 experiments were performed. The machining operation performed on vertical machining centre without using coolant. The surface roughness was measured by the device Surface Roughness Tester. These experimental data were analyzed using Minitab software to identify the most significant factor. The material used in this project is Al6082 Aluminium alloy.*

Keywords: *Surface Roughness, Taguchi, ANOVA, Minitab, End mill.*

1. INTRODUCTION

It is impossible to produce perfectly smooth surface by machining or other process. It means that by machining process some roughness is always present on the surface, which can varies according to changes the machining parameter. Surface roughness is very important factor which affect the surface quality of the product.

The surface roughness is the finer irregularities (peaks and valleys) of the surface. Surface roughness is a component of surface texture. It is describe by the deviations in the direction of the normal vector of a real surface. These deviations are depends on the surface quality. The surface is rough if these deviations are large and surface is smooth if these deviations are small.

2. LITERATURE REVIEW

The many researchers have research on material Al6082, but very few researchers has research work on End milling operation on Al6082. In this present work we are selected the material Al6082. The objective of present work is to optimize the cutting parameter of Al6082 in dry end milling operation.

Shetty et al. [1] (2008) were conducted an experiment and used Taguchi and Response Surface Methodologies for minimizing the surface roughness in turning of discontinuously reinforced aluminium composites (DRACs) having aluminium alloy 6061 as the matrix and containing 15 vol.% of silicon carbide particles of mean diameter 25 lm under pressured steam jet approach. They found the optimum condition for minimum surface roughness.

Muammer Nalbant et al. [2] (2009) were conducted an experiment and seen the effects of machining on AISI 1030 steel uncoated, PVD- and CVD-coated cemented carbide insert variation in feed rates, cutting speeds while keeping depth of cuts constant. This process was done without using cooling liquids. The result shows that a negative relationship between the average surface roughness and cutting speed for this tool. The surface roughness was decreased by increasing cutting speed.

Yallese et al. [3] (2010) were conducted the experiment for cutting forces in dry turning operation of AISI 52100 hot work-piece steel (50 HRC). They performed 27 experiments and specified effects of parameters like cutting speed, feed rate and depth of cut. They found that the most important factor affecting the components of the cutting forces was depth of cut.

Sahoo [4] (2011) was conducted an experimental study to investigate the effects of cutting speed, feed rate and depth of cut for minimum surface roughness for AISI 1040 steel when the material were machined on a CNC turning machine (lathe). ANOVA software was use to analysed the result for purpose of optimising the parameter.

Yansong Guo et al.[5] (2012) were conducted an experiments and seen the effects of an approach which incorporates both energy consumption and surface roughness for optimizing the cutting parameters in finish turning. This was based on a surface roughness model, they were optimized the cutting parameters for surface finish with minimum energy consumption. The analysis were done in two-step approach in determining the optimal cutting parameters for finishing turning operations for minimum energy consumption, by specified a surface finish.

Kamal Hassan et al.[6] (2012) were conducted an experiment and seen the effects of process parameters on Material Removal Rate (MRR) in turning operation of material C34000. The Cutting speed, feed rate and depth of cut were taken cutting parameters in this experiment and result were analysed ANOVA in MINITAB 16 @ software. The cutting speed and feed rate were most dominated factor for MRR. The conclusion shows that the MRR rate was increased by increasing the cutting speed and feed rate.

Upinder Kumar Yadav et al. [7] (2012) were conducted an experiment and optimized machining parameters for surface roughness in CNC turning by Taguchi method. The result shows that the feed rate and cutting speed were most dominant factor for minimum surface roughness and the surface roughness was increased with increasing the feed rate & decreasing the cutting speed.

Ilhan Asiltürk et al. [8] (2012) were conducted an experiment and optimized machining parameters for surface roughness in turning operation. Taguchi method was used to found the optimal turning process parameters. The result was analysed by both Taguchi and RSM method and it shows that the feed rate was the most significant factor for surface roughness.

Najiha M.S. et al. [9] (2013) were conducted an experiment to determine the optimum cutting parameters for the end milling process of Aluminium alloy 6061T6 under wet cooling conditions. The response surface methodology was used for optimizing the surface roughness. The result shows that the feed rate and the depth of cut was the most significant factors for surface roughness.

M Saravana Kumar et al. [10] (2014) were conducted an experiment to determine optimum micro milling parameters of AL-6082 by using DOE concept. The cutting speed, feed rate and depth of cur were chosen the process parameter. The result shows that MRR was decreased with decreasing the tool diameter, spindle speed and feed rate.

Nisha Tamta et al. [11] (2015) were conducted an experiment for optimum drilling machining process for Surface roughness (Ra) using Taguch method on material Aluminium Alloy 6082. The result shows that the drilling depth was the most significant factor follow by feed rate for roughness Ra.

K. Siva Kumar et al. [12] (2015) were conducted an experiment for optimum cutting parameters in CNC End milling of Aluminium Alloy 6082. RS methodology was selected to optimize the surface roughness. The result shows that the depth of cut was the influencing parameter followed by Speed and feed for Ra.

Rishi raj singh et al. [13] (2016) were conducted an experiment to determine optimum parameter for minimum surface roughness in CNC end milling. The response surface methodology was used for this experiment. The result shows that cutting speed to be the most significant and influential machining parameter followed by feed rate. The surface roughness was increased by increasing the feed but decreased by increasing the cutting speed and nose radius.

Anurag Salankar et al. [14] (2017) were conducted an experiment on extruded brass-lead alloy and inconel625 made of nickel and chromium due to their high strength, wear resistance and fatigue resistance. The machining was performed on the vertical milling centre using HSS tool material. The result was compared by graphically for different process parameters, performance parameters evaluated and concluding optimizing process parameters.

S. Sakthivelu et al. [15] (2017) were conducted an experiment on Aluminium Alloy 7075 T6 in CNC milling machine using High Speed Steel (HSS) cutting tool for high quality of surface finish and metal removal rate. The result shows that depth of cut was the most influencing parameter for material removal rate followed by feed and cutting speed.

3. EXPERIMENTAL DESIGN

3.1 Taguchi Method

The Taguchi Methods was developed by was Genichi Taguchi. He was a Japanese engineer who began working for the telecommunications company, Electrical Communications Lab, a part of NT&T, in 1950's. Taguchi method is used evaluating and implementing improvements in the products, optimization of the objectives function. Optimization means determination of best levels of control factors that maximize the signal-to – noise ratio.

3.2 Signal- to- Noise Ratio

Signal-to-noise ratio is very important and useful parameter in taking into account of goal and variation in comparing two sets of samples. Signal–to- noise ratio is the log functions of a given output. It is used for optimization of objectives function. It is also help in data analysis and prediction of results. Signal to noise ratio formula are as follow-

- Smaller the better

$$SNs = -10\log\left(1/n\sum_{i=1}^{n} Yi^2\right)$$

- Nominal the best

$$SNt = 10\log(\bar{y}_i^2/S^2)$$

- Larger the better

$$SN_l = -10\log\left(1/n\sum_{i=1}^{n} 1/Yi^2\right)$$

4. EXPERIMENTAL WORK

4.1 Workpiece Material

The material used in this research is Aluminium Alloy 6082. It is a medium strength alloy with highly corrosion resistant. The Aluminium alloy 6082 has highest strength of the 6000 series. It is mostly used in high stress application, trusses, bridges, cranes and transport application etc. The material properties are shown in the above table.

Table -1: Material Properties

Density	2.71 g/cm³
Young modulus	71 GPa
UTS	140 to 330 MPa
Yield strength	90 to 280 MPa
Hardness Brinell	91 HB
Material composition	Al- 95.2 to 98.3% Cr- 0.25% max Cu- 0.1% max Fe- 0.5% max Mg- 0.6 to 1.2% Mn- 0.4 to 1% Si- 0.7 to 1.3% max Ti- 0.1% max Zn- 0.2% max

Fig -1: Workpiece

4.2 CNC Vertical machining Centre

CNC Vertical Machining Centre is an automatic machine tool which is controlled by computer executes pre-programmed commands. The machine is moved along three x, y and z axis. The table is controlled in x and y axis and machine spindle move along z axis. The G and M codes are used to control the machine. These codes are based on the three dimensional Cartesian coordinate system. In CNC vertical machining centre the cutting tool is hold on a vertical spindle and feed is provided by the machine table.

Fig -2: Vertical Machining Centre

Table -2: VMC Specification

Machine Specification	
M/C model no.	TURBO-450-R40
Serial no.	6225/1215/66844
Capacity	450 W/hr
Spindle speed	6000 rpm
Temperature range	10^0 to 45^0 C
Frequency	50 HZ
Coolant System	
Tank capacity	450 litter
Type of coolant	Servo Cut-S
Coolant/water ratio	1:20
Coolant around spindle	50 lpm @ 1.8 bar
Coolant wash	60 lpm @ 4 bar
Lubrication System	
Tank capacity	3 litter
Type of oil	Servo way- H68
Max. working pressure	15 bar

4.3 Cutting Tool or End Mill

In this operation multipoint end milling cutter is used for machining. The material of cutting tool is carbide. The diameter of the cutting tool is 10 mm.

Fig -3: End Mill

4.4 Surface Roughness Tester

The portable stylus surface roughness tester is used to measure the surface roughness. The stylus moves on the peaks and valleys of the surface. The vertical motion of the stylus is converted into electrical signal by the transducer. This signal is in analog form. By using analog to digital converter these signal are converted into digital form and display the reading.

Fig - 4: Surface Roughness Tseter

4.5 Machining Parameter and Levels of Experiment

Table -3: Levels of Experiment

Parameter / Levels	speed(N) in rpm	Feed(f) in mm/ min.	Depth of Cut(d) in mm
Level 1	800	100	0.5
Level 2	1200	150	1.0
Level 3	1600	200	1.5

The spindle speed, depth of cut and feed rate are chosen the machining parameters. Also select the three levels of experiment.

4.6 Experimental Data

By using Minitab software orthogonal array is prepared and conduct the experiment, then with the help of surface roughness tester measured the roughness. Then we get the following experimental data.

Table -4: Experimental Data

Expt. no.	Speed (N)	Feed (f)	Depth of cut (d)	Cutter dia. (D)	Cutting Speed (V)	MRR	Avg. Rough. (Ra)	RMS Rough. (Rq)	S/N
	rpm	mm/min	mm	mm	m/min.	mm³/sec	mm	mm	db
1	800	100	0.5	10	25.132	08.33	0.93	1.15	0.6303
2	800	100	1.0	10	25.132	16.66	1.06	1.29	-0.5061
3	800	100	1.5	10	25.132	25.00	0.79	0.98	2.0475
4	800	150	0.5	10	25.132	12.50	1.78	2.38	-5.0084
5	800	150	1.0	10	25.132	25.00	1.82	2.26	-5.2014
6	800	150	1.5	10	25.132	37.50	1.97	2.44	-5.8893
7	800	200	0.5	10	25.132	16.67	3.11	3.91	-9.8552
8	800	200	1.0	10	25.132	33.33	3.97	4.96	-11.9758
9	800	200	1.5	10	25.132	50.oo	5.22	6.36	-14.3534
10	1200	100	0.5	10	37.698	08.33	0.91	1.12	0.8192
11	1200	100	1.0	10	37.698	16.67	0.60	0.72	4.4370
12	1200	100	1.5	10	37.698	25.00	1.79	2.30	-5.0571
13	1200	150	0.5	10	37.698	12.50	1.79	2.25	-5.0571
14	1200	150	1.0	10	37.698	25.00	0.69	0.86	3.2230
15	1200	150	1.5	10	37.698	37.50	0.78	0.96	2.1581
16	1200	200	0.5	10	37.698	16.67	1.89	2.36	-5.5292
17	1200	200	1.0	10	37.698	33.33	1.24	1.52	-1.8684
18	1200	200	1.5	10	37.698	50.00	1.52	1.84	-3.6369
19	1600	100	0.5	10	50.264	08.33	0.61	0.73	4.2934
20	1600	100	1.0	10	50.264	16.67	0.71	0.87	2.9748
21	1600	100	1.5	10	50.264	25.00	0.71	0.83	2.97483
22	1600	150	0.5	10	50.264	12.50	0.80	0.97	1.93820
23	1600	150	1.0	10	50.264	25.00	0.88	1.07	1.11035
24	1600	150	1.5	10	50.264	37.50	0.68	0.89	3.34982
25	1600	200	0.5	10	50.264	16.67	0.60	0.74	4.43697
26	1600	200	1.0	10	50.264	33.33	1.03	1.32	-0.25674
27	1600	200	1.5	10	50.264	50.00	0.83	1.03	1.61844

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5. RESULT ANALYSIS

The experimental data are analysed in Minitab software we get the following result.

Table -5: Response Table for Signal to Noise Ratios

Level	N	F	D
1	-5.5680	1.4015	-1.4813
2	-1.1679	-1.0419	-0.8959
3	2.4933	-4.6023	-1.8653
Delta	8.0613	6.0038	0.9694
Rank	1	2	3

Table -6: Response Table for Average Roughness

Level	N	F	D
1	2.2944	0.9011	1.3800
2	1.2456	1.2433	1.3333
3	0.7611	2.1567	1.5878
Delta	1.5333	1.2556	0.2544
Rank	1	2	3

It is clear that from both the table, the rank of spindle speed, feed and depth of cut are 1, 2 and 3 respectively. It means that the surface roughness is maximum affected by speed follow by feed and depth of cut.

5.1 Effect of Machining Parameters on Surface Roughness and S/N Ratio

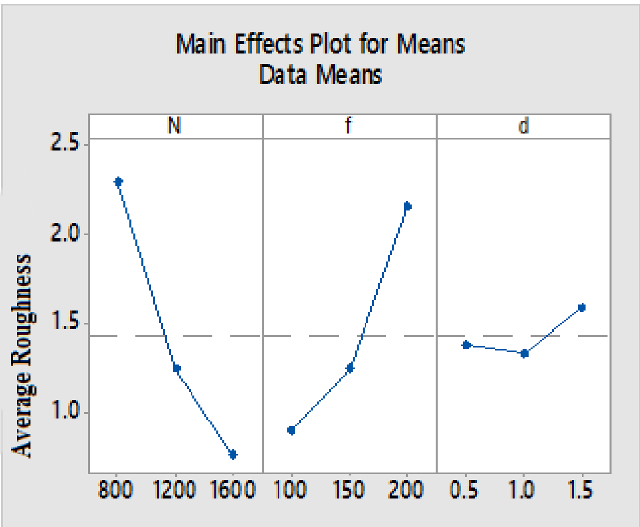

Fig -5: Effects of machining parameter on surface roughness

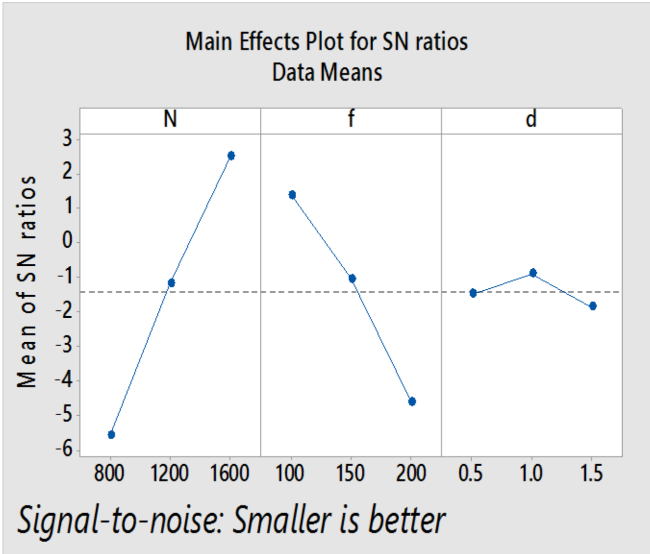

Fig -6: Effects of machining parameter on S/N Ratio

It is clear from figure -5 surface roughness decreases with increasing spindle speed and increases with increasing feed rate. Also from figure-6 it is clear that S/N ratio increases with increasing spindle speed and decreases with increasing feed rate.

5.2 Surface Plot with machining Parameters

Surface plot with variation of machining parameters are given below.

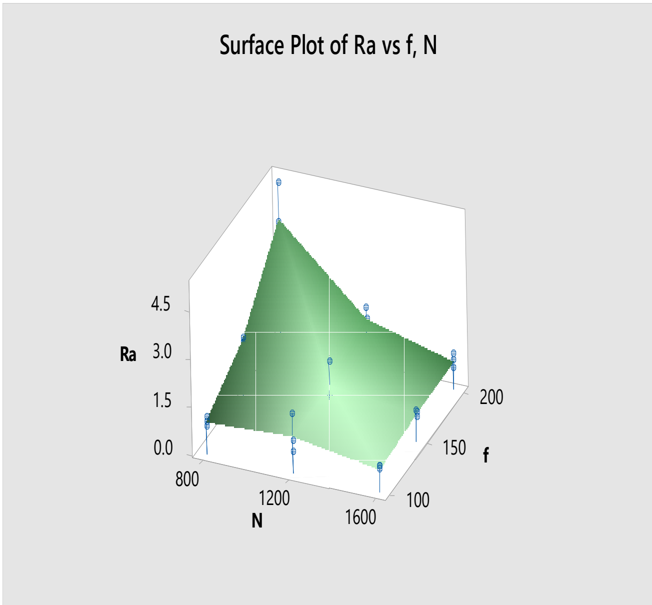

Fig -7: Surface Plot with feed and speed

This figure shows that the surface is plot with the variation of feed and depth of cut. Similarly figure -8 and figure -9 shows that the surface is plot with the variation of other machining parameters.

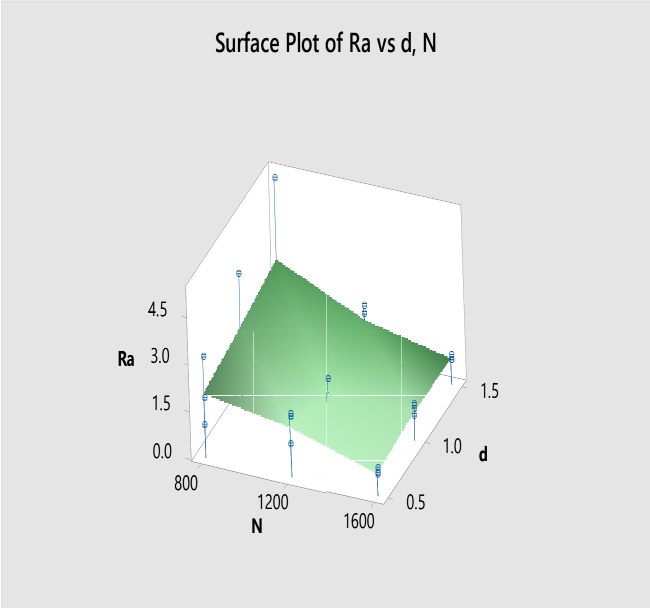

Fig -8: Surface Plot with Speed and Depth of Cut

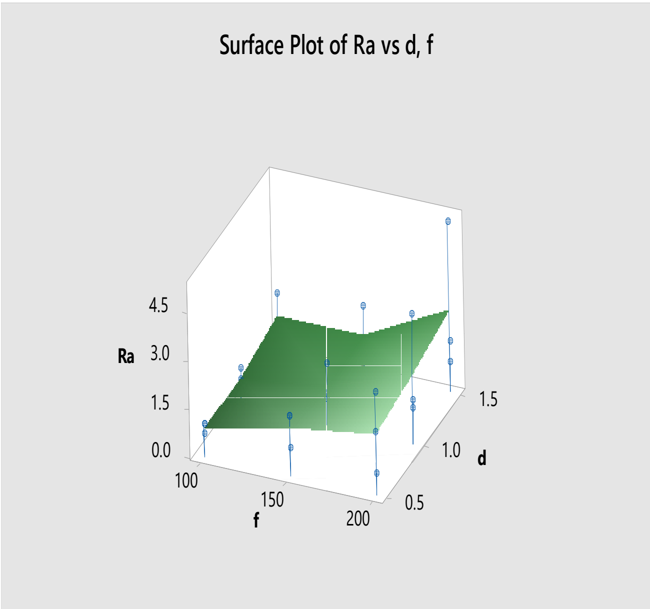

Fig -9: Surface Plot with Feed and Depth of Cut

6. CONCLUSIONS

In this research work we are selected the material Aluminium alloy 6082 for optimization of machining parameters spindle speed, feed and depth of cut for minimum surface roughness in dry end milling operation. Taguchi method is used to optimize these parameters. According to L_{27} orthogonal array 27 experiments are performed. The experimental data is analysed in Minitab software and we get the following result.

Factor	Rank
Speed	1
Feed	2
Depth of cut	3

- Speed, feed and depth of cut have rank 1, 2 and 3 respectively. It means that the surface roughness is maximum affected by the speed followed by feed and depth of cut.
- The surface roughness decreases with increasing spindle speed and increases with increasing feed rate.
- The optimum values of machining parameter for minimum surface roughness in dry end milling operation are speed 1600 rpm, feed 100 mm per min. and depth of cut 1.0 mm.

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