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Experimental Investigation of Surface Roughness and MRR in Milling of Aluminum Alloy 6082 using Taguchi Technique

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Abstract: In this thesis experiments are conducted to enhance the surface quality, material removal rate of Aluminum 6082 alloy work piece. A series of twelve experiments are performed by variable milling parameters spindle speed 1800rpm, 3000rpm, feed rate 200mm/min, 500mm/min, depth of cut 0.3mm, 0.5mm, cutting fluids Synthetic, Semi Synthetic and cutting toolSolid Carbide, Carbide Insert and to optimize the higher machining parameters using Taguchi technique. The millingprocess is conducted on a CNC Vertical Milling Machine.

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I. Introduction to Milling

Milling is a cutting method that uses a milling cutter to get rid of material from the surface of a work- piece. The milling cutter could be a rotary-cutting tool, typically with multiple cutting points. As against drilling, wherever the tool is advanced on its rotation axis, the cutter in milling is advanced perpendicular to its axis in order that cutting happens on the circumference of the cutter. Because the edge cutter enters the work-piece, the cutting edges (flutes or teeth) of the tool repeatedly turn over and exit from the material, shaving off chips (swarf) from the work-piece with every pass. The cutting action is shear deformation; material is pushed off the work-piece in little clumps that interdependent to a larger or lesser extent (depending on the material) to make chips. This makes metal cutting somewhat totally different (in its mechanics) from slicing softer materials with a blade.

Choice of operating conditions

- Cutting speed parameter
- Feed rate parameter
- Engagement parameter

CNC Material Removal Rate (MRR)

MRR in milling

D: Depth of cut, mm.
W: Width of cut, mm.
F: Feed rate, mm/min

MRR = D x W x F cc/min.

1.8 INTRODUCTION TO SURFACE ROUGHNESS

Roughness plays a very important role in deciding however a true object can move with its atmosphere. Rough surfaces typically wear a lot of quickly and have higher friction coefficients than swish surfaces. Roughness is commonly a decent predictor of the performance of a mechanical element, since irregularities within the surface might kind nucleation sites for cracks or corrosion. On the opposite hand, roughness might promote adhesion.

I. INTRODUCTION TO T AGUCHI METHOD

A calculatedly set of experiments, within which all parameters of interest are varied over a such vary, could be a far better approach to get systematic information. Mathematically speaking, such an entire set of experiments need to provide desired results. Typically the quantity of experiments and resources (materials and time) needed are prohibitively giant.

Dr. Taguchi of Nihon Telephones and Telegraph Company, Japan has developed a way supported "ORTHOGONALARRAY" experiments which supplies abundant reduced "variance" for the experiment with "optimum settings" of management parameters. Therefore the wedding of style of Experiments with optimisation of management parameters to get BEST results is achieved within the Taguchi technique. "Orthogonal Arrays" (OA) offer a group of well balanced (minimum) experiments and Dr. Taguchi's Signal toNoise ratios (S/N), that area unit log functions of desired output, function objective functions for optimization, facilitate in information analysis and prediction of optimum results.

II. LITERATURE REVIEW

The following are the works done by completely different authors on machining of milling:

In the work done by DrazenBajic[1], examined the influence of 3 cutting parameters on surface roughness, tool wear and cutting force parts in face milling as a part of the off-line method management. The experiments were allotted so as to outline a model for method designing. Cutting speed, feed per tooth and depth of cut were taken as powerful factors.In the work done by B. Siddareddy[2], the experiments were conducted exploitation Taguchi's L50 orthogonal array within the style of experiments (DOE) by considering the machining parameters like nose radius (r), cutting speed (v), feed (f), axial depth of cut (d) and radial depth of cut(rd). A prophetical response surface model for surface roughness is developed exploitation RSM. The response surface (rs) model is interfaced with the genetic algorithmic rule (ga) to seek out the optimum machining parameter values. In this paper done by Sharkawy [6], the contribution is to analyze completely different methodologies that may be accustomed get the most effective prediction accuracy. The procedure is illustrated exploitation experimental knowledge of end-milling 6061 metal alloy. The 3 networks are trained exploitation experimental coaching knowledge. When coaching, they need been examined exploitation another set of information. **Objective of The Project:**In this thesis experiments are conducted to improve the surface finish quality and material removal rate of Aluminum alloy 6082. A series of experiments are conducted by varying the milling parameters spindle speed, feed rate, depth of cut, cutting tool material and cutting fluid. Experiments are conducted on 12 components by selecting the parameters as per L12 orthogonal array in Taguchi method. After machining, surface roughness values are observed and the parameters are optimized from the observations for the least value. Material Removal Rates are also determined and optimized for higher values.The machining parameters used for Spindle Speed – 1800rpm, 3000rpm, Feed Rate – 200mm/min, 500mm/min , depth of cut – 0.3mm, 0.5mm, Cutting tool - Carbide, Carbide Insert and cutting fluid – Synthetic oil , Semi-SyntheticOils.

III. EXPERIMENTAL SETUP AND PROCEDURE

In this thesis experiments are conducted to improve the surface finish quality and material removal rate of Aluminum alloy 6082. A series of experiments are conducted by varying the milling parameters spindle speed, feed rate, depth of cut, cutting tool material and cutting fluid. Experiments are conducted on 12 components by selecting the parameters as per L12 orthogonal array in Taguchi method. After machining, surface roughness values are observed and the parameters are optimized from the observations for the least value. Material Removal Rates are also determined and optimized for higher values.

Experimental Procedure

This experiment employed a CNC vertical milling machine. The machining parameters used for Spindle Speed – 1800rpm, 3000rpm, Feed Rate – 200mm/min, 500mm/min , depth of cut – 0.3mm, 0.5mm, Cutting tool – Solid Carbide, Carbide Insert and Cutting fluid – Synthetic oil , Semi-SyntheticOils,

Size of Component

Length – 200mm

Width – 60mm

Height – 20mm

Machine Specifications

Machine Model – Feeler

Control – Siemens 840d

Travel Size X – 1000mm, Y – 500mm, Z – 500mm

Cutters used

Solid Carbide Cutter - 50R6 bull nose cutter

Carbide Insert - New Insert used for this cutter is R6 carbide insert, HITACHI

Taguchi Parameter Design for Milling Process

In order to identify the process parameters affecting the selected machine quality characteristics of milling, the following process parameters are selected for the present work: cutting speed, feed rate and depth of cut, cutting tool and cutting fluid. The selection of parameters of interest and their ranges is based on literature review and some preliminary experiments conducted.

Parameters used for Machining

JOB NO.	Speed (rpm)	Feed Rate (mm/min)	Depth of cut (mm)	Cutting Tool	Cutting Fluid
1	1800	200	0.3	Solid Carbide	Synthetic
2	1800	200	0.3	Solid Carbide	Synthetic
3	1800	200	0.5	Carbide Insert	Semisynthetic
4	1800	500	0.3	Carbide Insert	Semisynthetic
5	1800	500	0.5	Solid Carbide	Semisynthetic

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6	1800	500	0.5	Carbide Insert	Synthetic
7	3000	200	0.5	Carbide Insert	Synthetic
8	3000	200	0.5	Solid Carbide	Semisynthetic
9	3000	200	0.3	Carbide Insert	Semisynthetic
10	3000	500	0.5	Solid Carbide	Synthetic
11	3000	500	0.3	Carbide Insert	Synthetic
12	3000	500	0.3	Solid Carbide	Semisynthetic

Table.1. Process Parameters taken for machining

Fig.1. Machining of work piece by applying parameters – Spindle Speed 1800rpm, Feed Rate – 200mm/min and Depth of Cut – 0.5mm, Solid Carbide Tool, Cutting Fluid – Semi Synthetic oil

IV. Surface Finish Results

The following are the surface roughness values observedafter machining for 12 experiments for both solid carbide tool and insert tool.

JOB NO.	**Speed (rpm)**	**Feed Rate (mm/min)**	**Depth of cut (mm)**	**Cutting Tool**	**Cutting Fluid**	**Surface Roughness (R_a)**
1	1800	200	0.3	Solid Carbide	Synthetic	2.89
2	1800	200	0.3	Solid Carbide	Synthetic	2.88
3	1800	200	0.5	Carbide Insert	Semisynthetic	2.81
4	1800	500	0.3	Carbide Insert	Semisynthetic	2.74
5	1800	500	0.5	Solid	Semisynthetic	2.77

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				Carbide		
6	1800	500	0.5	Carbide Insert	Synthetic	2.75
7	3000	200	0.5	Carbide Insert	Synthetic	2.54
8	3000	200	0.5	Solid Carbide	Semisynthetic	2.31
9	3000	200	0.3	Carbide Insert	Semisynthetic	2.08
10	3000	500	0.5	Solid Carbide	Synthetic	2.33
11	3000	500	0.3	Carbide Insert	Synthetic	2.12
12	3000	500	0.3	Solid Carbide	Semisynthetic	2.27

Table.2. Measured Surface Roughness Values

Material Removal Rate

Material Removal rate is calculated by taking Initial weight and final weight of work piece after machining for each 12 experiments and the time taken for machining.

JOB NO.	**Speed (rpm)**	**Feed Rate (mm/min)**	**Depth of cut (mm)**	**Cutting Tool**	**Cutting Fluid**	**Material Removal Rate (mm^3/sec)**
1	1800	200	0.3	Solid Carbide	Synthetic	15
2	1800	200	0.3	Solid Carbide	Synthetic	15
3	1800	200	0.5	Carbide Insert	Semisynthetic	25
4	1800	500	0.3	Carbide Insert	Semisynthetic	37.5
5	1800	500	0.5	Solid Carbide	Semisynthetic	62.5
6	1800	500	0.5	Carbide Insert	Synthetic	63.9
7	3000	200	0.5	Carbide Insert	Synthetic	23.5
8	3000	200	0.5	Solid Carbide	Semisynthetic	24.4
9	3000	200	0.3	Carbide Insert	Semisynthetic	17.2
10	3000	500	0.5	Solid Carbide	Synthetic	61.1
11	3000	500	0.3	Carbide Insert	Synthetic	35.2
12	3000	500	0.3	Solid	Semisynthetic	35.9

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				Carbide		

Table.3. MeasuredMRR Values

V. Optimization of Machining Parameters for Higher Material Removal Rates and Lesser Surface Roughness using Minitab Software

Surface Roughness

In this project, Taguchi method is used to optimize the process parameters Speed, Feed rate, Depth of cut, Cutting tool and Cutting fluid for lesser surface roughness values. The optimization is done in Minitab 17 software.

2-Level Design and No. of factors - 5

Enter Surface Roughness Values in the table

Worksheet 1 ***

↓	C1	C2	C3	C4-T	C5-T	C6
	Speed (rpm)	Feed Rate (mm/min)	Depth of cut (mm)	Cutting Tool	Fluid	Surface Roughness
1	1800	200	0.3	Solidcarbide	Synthetic	2.89
2	1800	200	0.3	Solidcarbide	Synthetic	2.88
3	1800	200	0.5	CarbideInsert	Semisynthetic	2.81
4	1800	500	0.3	CarbideInsert	Semisynthetic	2.74
5	1800	500	0.5	Solidcarbide	Semisynthetic	2.77
6	1800	500	0.5	CarbideInsert	Synthetic	2.75
7	3000	200	0.5	CarbideInsert	Synthetic	2.54
8	3000	200	0.5	Solidcarbide	Semisynthetic	2.31
9	3000	200	0.3	CarbideInsert	Semisynthetic	2.08
10	3000	500	0.5	Solidcarbide	Synthetic	2.33
11	3000	500	0.3	CarbideInsert	Synthetic	2.12
12	3000	500	0.3	Solidcarbide	Semisynthetic	2.27

Fig.2. Observed Surface Roughness values from experimentation

Options – Smaller is better

Results Table

↓	C1	C2	C3	C4-T	C5-T	C6	C7
	Speed (rpm)	Feed Rate (mm/min)	Depth of cut (mm)	Cutting Tool	Fluid	Surface Roughness	SNRA1
1	1800	200	0.3	Solidcarbide	Synthetic	2.89	-9.20293
2	1800	200	0.3	Solidcarbide	Synthetic	2.88	*
3	1800	200	0.5	CarbideInsert	Semisynthetic	2.81	-8.97413
4	1800	500	0.3	CarbideInsert	Semisynthetic	2.74	-8.75501
5	1800	500	0.5	Solidcarbide	Semisynthetic	2.77	-8.84960
6	1800	500	0.5	CarbideInsert	Synthetic	2.75	-8.78665
7	3000	200	0.5	CarbideInsert	Synthetic	2.54	-8.09667
8	3000	200	0.5	Solidcarbide	Semisynthetic	2.31	-7.27224
9	3000	200	0.3	CarbideInsert	Semisynthetic	2.08	-6.36127
10	3000	500	0.5	Solidcarbide	Synthetic	2.33	-7.34712
11	3000	500	0.3	CarbideInsert	Synthetic	2.12	-6.52672
12	3000	500	0.3	Solidcarbide	Semisynthetic	2.27	-7.12052

Table.4. Calculated Signal to Noise Ratios for Smaller is better

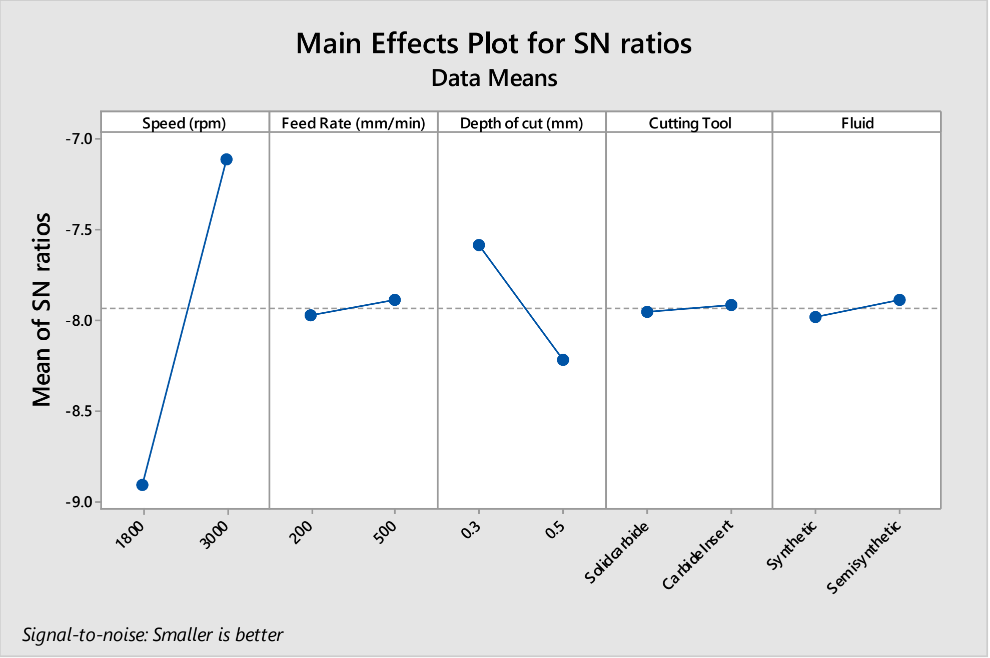

Fig.3. Effect of machining parameters on Surface Roughness for S/N ratio for Smaller is better

Speed:-The effect of parameter Speed on Surface Roughness is shown above figure S/N ratio. So the optimum Speedis 3000rpm.

Feed Rate:-The effect of parameter feed rate on Surface Roughness is shown above figure S/N ratio. So the optimum feed rate is 500mm/min.

Depth of cut:-The effect of parameter Depth of cut on Surface Roughness is shown above figure S/N ratio. So the optimum Depth of cut is 0.3mm.

Cutting Tool:-The effect of parameter cutting tool on Surface Roughness is shown above figure S/N ratio. So the optimum cutting toolis Carbide Insert.

Cutting Fluid:-The effect of parameter cutting Fluid on Surface Roughness is shown above figure S/N ratio. So the optimum cutting fluidis Semi Synthetic.

MRR

Options – Larger is better

Results Table

↓	C1	C2	C3	C4	C5	C6	C7
	Thickness (mm)	Standoff Distance (mm)	Feed Rate (rpm)	Exit Water Velocity (mm/min)	Pressure (Psi)	Surface Roughness	SNRA3
1	6	5	450	140	50000	4.822	-13.6627
2	6	5	450	140	50000	4.820	*
3	6	5	600	350	60000	4.780	-13.5886
4	6	10	450	350	60000	4.850	-13.7148
5	6	10	600	140	60000	4.670	-13.3863
6	6	10	600	350	50000	4.800	-13.6248
7	8	5	600	350	50000	4.726	-13.4899
8	8	5	600	140	60000	4.690	-13.4235
9	8	5	450	350	60000	4.880	-13.7684
10	8	10	600	140	50000	4.700	-13.4420
11	8	10	450	350	50000	4.910	-13.8216
12	8	10	450	140	60000	4.860	-13.7327

Table.5. Calculated Signal to Noise Ratios for Larger is better

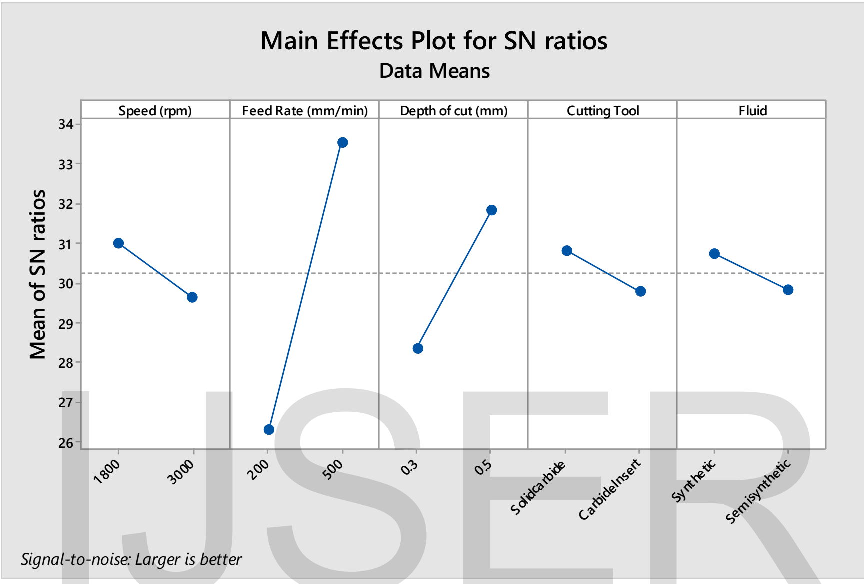

Fig.4. Effect of machining parameters on Surface Roughness for S/N ratio for Smaller is better

Speed:-The effect of parameter Speed on Surface Roughness is shown above figure S/N ratio. So the optimum Speedis 1800rpm.

Feed Rate:-The effect of parameter feed rate on Surface Roughness is shown above figure S/N ratio. So the optimum feed rate is 500mm/min.

Depth of cut:-The effect of parameter Depth of cut on Surface Roughness is shown above figure S/N ratio. So the optimum Depth of cut is 0.5mm.

Cutting Tool:-The effect of parameter cutting tool on Surface Roughness is shown above figure S/N ratio. So the optimum cutting toolis Solid Carbide.

Cutting Fluid:-The effect of parameter cutting Fluid on Surface Roughness is shown above figure S/N ratio. So the optimum cutting fluidis Synthetic.

VI. Conclusion

By observing the experimental results the following conclusions can be made:For minimum surface roughness values, the optimum parameters are Speed- 3000rpm, feed rate - 500mm/min, Depth of cut -

0.3mm, cutting tool- Carbide Insert and cutting fluid- Semi Synthetic. For maximum MRR values, the optimum parameters are Speed- 1800rpm, feed rate - 500mm/min, Depth of cut - 0.5mm, cutting tool– Solid Carbide and cutting fluid- Synthetic.

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