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Increasing the Surface Finish Quality and Mrr by Varying Milling Parameters for Aluminum Alloy2024

M.Bharat Santosh Kumar & Missr.Anusha

M.BHARAT SANTOSH KUMAR received the B.Tech degree in mechanical engineering from ADARSH COLLEGE OF ENGINEERING, JNTU Kakinada, Chebrolu Andhra Pradesh, India, in 2013 year, and perusing M.Tech in CAD/CAM from Kakinada Institute Of Technology And Science, Divili, Peddapuram Andhra Pradesh, India.

MissR.ANUSHA, M.Tech, Assistant professor, Kakinada Institute Of Technology And Science, Divili, Peddapuram Andhra Pradesh, India.

ABSTRACT

The main objective of this project is to optimize the process parameters in milling to achieve better surface finish and higher material removal rates using different cutting tools.

Different experiments are conducted to optimize the process parameters to improve the surface finish quality and material removal rate while machining Aluminum alloy AA 2024. A series of experiments aredone by varying the milling parameters spindle speed, feed rate, depth of cut and tool material considering L16 orthogonal array by Taguchi method. The optimization is done for least surface roughness and high material removal rates.

The experiment has been done with process parameters feed rate 80mm/min, 100mm/min, 120mm/min, 140 mm/min, spindle speeds are 800rpm, 1000rpm, 1200rpm, 1400rpm, and depth of cut 0.5mm, 1mm, 1.5mm and 2mm.

INTRODUCTION

Metal cutting is one of the most important and widely used manufacturing processes in engineering industries and in today's manufacturing scenario, optimization of metal cutting process is essential for a manufacturing unit to respond effectively to severe competitiveness and increasing demand of quality which has to be achieved at minimal cost. As flexibility and adaptability needs increased in the manufacturing industries, computer numerical control systems was introduced in metal cutting processes that provided automation of processes with very high accuracies and repeatability. Because of high cost of numerically controlled machine tools compared to their conventional counterparts, there is an economic need to operate these machines as effectively as possible in order to obtain the required payback. Product quality, productivity and cost became important goals in manufacturing industries.

Based on the literature review it was evident that the factors that highly influence the process efficiency and output characteristics in a CNC machine tool are tool geometry, cutting velocity, feed rate, depth of cut and cutting environment. Experimental works have been carried out on the above mentioned parameters. A significant improvement in process efficiency may be obtained by process parameter optimization that identifies and determines the regions of critical process control factors leading to desired outputs or responses with acceptable variation ensuring a lower cost of manufacturing.

Of the many goals focused in a manufacturing industry, energy consumption plays a vital and dual role. One, it cuts down the cost per product and secondly the environmental impact by reducing the amount of carbon emissions that are created in using the electrical energy. Many have worked in optimizing the parameters of computer numerically controlled machine tools for minimum power requirement but in high tare machine tools, time dominates over power when optimizing for reduced energy.

The current work considers the most commonly selected process parameters viz. cutting velocity, feed rate and depth of cut optimized for minimum energy consumption.

Machining operations

The three principal machining processes are classified as turning, drilling and milling. Other operations falling into miscellaneous categories include shaping, planning, boring, broaching and sawing.

There are many kinds of machining operations, each of which is capable of generating a certain part geometry and surface texture.

In turning, a cutting tool with a single cutting edge is used to remove material from a rotating work-piece to generate a cylindrical shape. The primary motion is provided by rotating the work-piece, and the feed motion is achieved by moving the cutting tool slowly in a direction parallel to the axis of rotation of the work-piece.

Drilling is used to create a round hole. It is accomplished by a rotating tool that typically has two or four helical cutting edges. The tool is fed in a direction parallel to its axis of rotation into the work-piece to form the round hole.

In boring, a tool with a single bent pointed tip is advanced into a roughly made hole in a spinning work-piece to slightly enlarge the hole and improve its accuracy. It is a fine finishing operation used in the final stages of product manufacture.

Reaming is one of the sizing operations that remove a small amount of metal from a hole that already drilled.

In milling, a rotating tool with multiple cutting edges is moved slowly relative to the material to generate a plane or straight surface. The direction of the feed motion is perpendicular to the tool's axis of rotation. The speed motion is provided by the rotating milling cutter. The two basic forms of milling are:

- Peripheral milling
- Face milling.

Other conventional machining operations include shaping, planning, broaching and sawing. Also, grinding and similar abrasive operations are often included within the category of machining.

MILLING

Milling is the machining process of using rotary cutters to remove material from a work piece by advancing (or feeding) in a direction at an angle with the axis of the tool. It covers a wide variety of different operations and machines, on scales from small individual parts to large, heavy-duty gang milling operations. It is one of the most commonly used processes in industry and machine shops today for machining parts to precise sizes and shapes.

Milling can be done with a wide range of machine tools. The original class of machine tools for milling was the milling machine (often called a mill). After the advent of computer numerical control (CNC), milling machines evolved into machining centers (milling machines with automatic tool changers, tool magazines or carousels, CNC control, coolant systems, and enclosures), generally classified as vertical machining centers (VMCs) and horizontal machining centers (HMCs).

The integration of milling into turning environments and of turning into milling environments, begun with live tooling for lathes and the occasional use of mills for turning operations, led to a new class of machine tools, multitasking machines (MTMs), which are purpose-built to provide for a default machining strategy of using any combination of milling and turning within the same work envelope.

LITERATURE SURVEY

The following are the works done by different authors on machining of milling:
The work done by P. V. Rangarao[1], describes a comparison of tool life between ceramics and cubic boron nitride(CBN) cutting tools when machining hardened steels using the Taguchi method. An orthogonaldesign, signal-to-noise ratio (S/N) and analysis of variance (ANOVA) were employed to determinethe effective cutting parameters on the tool life. The results indicated that the V was found to be adominant factor on the tool life, followed by the TH, lastly the f. The CBN cutting tool showed thebest performance than that of ceramic based cutting tool. In addition, optimal testing parameter forcutting times was determined. The confirmation of Experiment was conducted to verify the optimaltesting parameter. Improvements of the S/N ratio from initial testing parameters to optimal cuttingparameters or prediction capability depended on the S/N ratio and ANOVA results. Moreover, theANOVA indicated that the cutting speed was higher significant but other parameters were alsosignificant effects on the tool lives at 90% confidence level. The percentage contributions of thecutting speed, tool's hardness, and feed rate were about 42.88, 32.44, and 24.22 on the tool life,respectively. The work done by A.K Ghani[2], presents a study of tool life, surface finish and vibration while machining nodular cast iron using ceramic tool. A series of cutting tests have been carried out to verify the change in surface finish of the workpiece due to increasing tool wear. The tests have been done under various combinations of speed, feed and depth of cut. The effects of vibration on the flank wear both in the direction of main cutting force and radial cutting force have been investigated. The vibration was measured using two accelerometers attached to the tool holder and the parameters used to make the correlation with surface roughness were the amplitude and acceleration of the signals.The results show that the tool life of the alumina ceramic inserts is not satisfactory when machining nodular cast iron. In the speed range 364–685 m/min, maximum tool life achieved was only about 1.5 min. Surface finish was found to be almost constant with the progression of the flank wear under all cutting conditions. It has been observed that for the same flank wear, vibration during cutting decreases as the speed increases. At low depth of cut, vibration remains almost constant with the increase of flank wear.

The work done by Abdullah Altin[3], the effects of cutting speed on tool wear and tool life when machining Inconel 718 nickel-based super alloy have been experimentally investigated. A series of tool life experiments has been carried out using silicon nitrite based and whisker reinforced ceramic tools which have two different geometries and three different ISO qualities with 10% water additive cutting fluid. The experiment results show that crater and flank wears are usually dominant wear types in ceramic square type (SNGN) inserts while flank and notch wear are dominant in round type (RNGN) inserts. Minimum flank wear is seen with SNGN tools at low cutting speeds while it is seen with RNGN tools at high cutting speeds.

The work done by A. Senthil Kumar [4], the advanced ceramic cutting tools have very good wear resistance, high refractoriness, good mechanical strength and hot hardness. Alumina based ceramic cutting tools have very high abrasion resistance and hot hardness. Chemically they are more stable than high-speed steels and carbides, thus having less tendency to adhere to metals during machining and less tendency to form built-up edge. This results in good surface finish and dimensional accuracy in machining steels. In this paper wear behaviour of alumina based ceramic cutting tools is investigated. The machining tests were conducted using SiC whisker reinforced alumina ceramic cutting tool and Ti[C,N] mixed alumina ceramic cutting tool on martensitic stainless steel-grade 410 and EN 24 steel work pieces. Flank wear in Ti[C,N] mixed alumina ceramic cutting tool is lower than that of the SiC whisker reinforced alumina cutting tool. SiC whisker reinforced alumina cutting tool exhibits poor crater wear resistance while machining. Notch wear in SiC whisker reinforced alumina cutting tool is lower than that of the Ti[C,N] mixed alumina ceramic cutting tool. The flank wear, crater wear and notch wear are higher on machining martensitic stainless steel than on machining hardened steel. In summary Ti[C,N] mixed alumina cutting tool performs better than SiC whisker reinforced alumina cutting tool on machining martensitic stainless steel.

The work done by Ali RizaMotorcu[5], the surface roughness in the turning of AISI 8660 hardened alloy steels by ceramic based cuttingtools was investigated in terms of main cutting parameters such as cutting speed, feed rate, depth of cut inaddition to tool's nose radius, using a statistical approach. Machining tests were carried out with PVDcoatedceramic cutting tools under different conditions. An orthogonal design, signal-to-noise ratio andanalysis of variance were employed to find out the effective cutting parameters and nose radius on thesurface roughness.The obtained results indicate that the feed rate was found to be the dominant factor amongcontrollable factors on the surface roughness, followed by depth of cut and tool's nose radius. However,the cutting speed showed an insignificant effect. Furthermore, the interaction of feed rate/depth of cutwas found to be significant on the surface finish due to surface hardening of steel. Optimal testingparameters for surface roughness could be calculated. Moreover, the second order regression model alsoshows that the predicted values were very close to the experimental one for surface roughness.

The work done by E. Ahmadi[6], the tool life of a cutting tool is an important critical factor in evaluatingits performance. The amount of tool abrasion seriously affects the dimensions andsurface quality of the working piece so that one of the main factors determining thetool life of a tool is the degree of wear. For this purpose, an abrasion standard isdefined for each particular tool above which the tool is no longer applicable. In thispaper, studies are concentrated on the machining of PH-hardened Austeniticferritic(Duplex) stainless steel (330HRC) to analyze the effect of tool wear on thetool life of the ceramic cutting tool with Alumina base (aluminium oxide). Theabrasion tool parameters like flank wear, crater wear, and notch wear have beenaddressed. To develop the mathematical models for the parameters studied in toolwear, the experimental results are applied in a multi-regression analysis (MRA)and the results obtained by these models are studied and analyzed by analysis ofvariance (ANOVA).

OPTIMIZATION OF MACHINING PARAMETERS USING MINITAB SOFTWARE

Factors	Units	Level 1	Level 2	Level 3	Level 4
Cutting speed, N	**rpm**	800	1000	1200	1400
Feed Rate, f	**mm/min**	80	100	120	140
Depth of cut, d	**mm**	0.5	1	1.5	2

Table – Process Parameters as per Taguchi Technique

Design of experiments for L16 orthogonal array

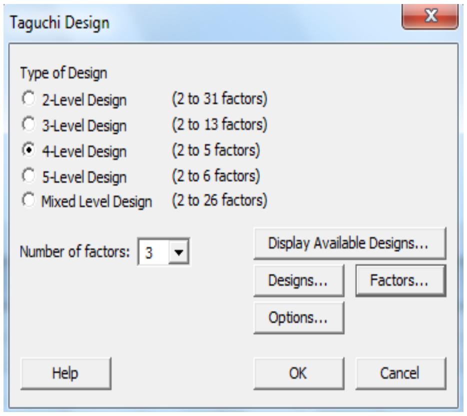
Job No.	Cutting speed (rpm)	Feed rate (mm/min)	Depth of cut (mm)
1	800	80	0.5
2	800	100	1
3	800	120	1.5
4	800	140	2
5	1000	80	1
6	1000	100	0.5
7	1000	120	2
8	1000	140	1.5
9	1200	80	1.5
10	1200	100	2
11	1200	120	0.5
12	1200	140	1
13	1400	80	2
14	1400	100	1.5
15	1400	120	1
16	1400	140	0.5

Table – L16 Orthogonal Array

Design of Orthogonal Array

First Taguchi Orthogonal Array is designed in Minitab17 to calculate S/N ratio which steps is given below:

Select 4-Level Design and No. of factors - 3

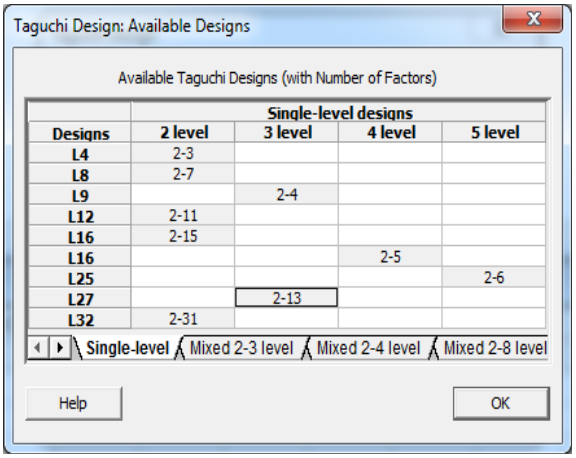

Taguchi Design

Type of Design
○ 2-Level Design (2 to 31 factors)
○ 3-Level Design (2 to 13 factors)
● 4-Level Design (2 to 5 factors)
○ 5-Level Design (2 to 6 factors)
○ Mixed Level Design (2 to 26 factors)

Number of factors: 3

Fig – 4-Level Design 3 Factors

Select Display Available Designs

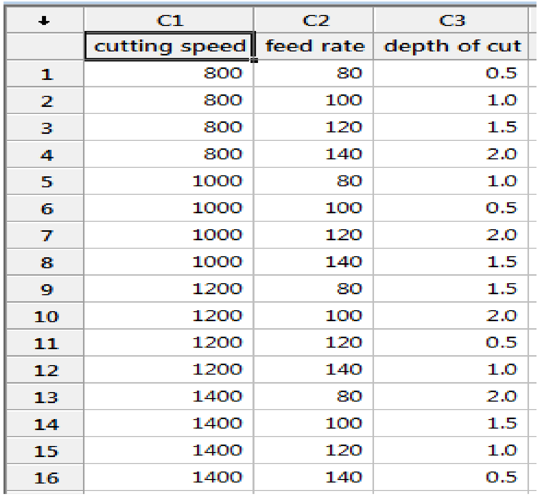


Taguchi Design: Available Designs

Available Taguchi Designs (with Number of Factors)

	Single-level designs			
Designs	2 level	3 level	4 level	5 level
L4	2-3			
L8	2-7			
L9		2-4		
L12	2-11			
L16	2-15			
L16			2-5	
L25				2-6
L27		2-13		
L32	2-31			

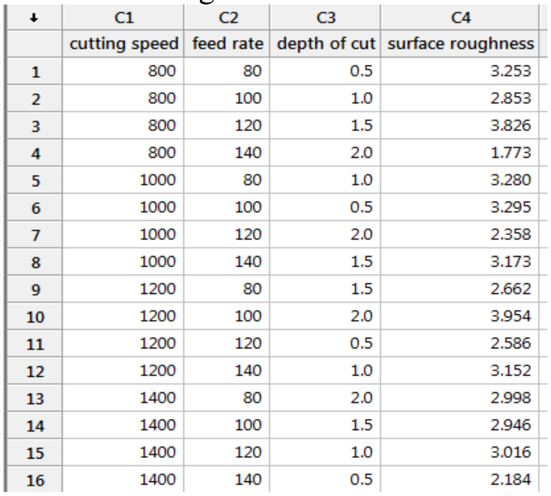
Fig – Selecting L16 (2-15) Taguchi design



	C1	C2	C3
	cutting speed	feed rate	depth of cut
1	800	80	0.5
2	800	100	1.0
3	800	120	1.5
4	800	140	2.0
5	1000	80	1.0
6	1000	100	0.5
7	1000	120	2.0
8	1000	140	1.5
9	1200	80	1.5
10	1200	100	2.0
11	1200	120	0.5
12	1200	140	1.0
13	1400	80	2.0
14	1400	100	1.5
15	1400	120	1.0
16	1400	140	0.5

Fig – Arrangement of L16 orthogonal array for given parameters

Enter Surface Roughness Values in the table



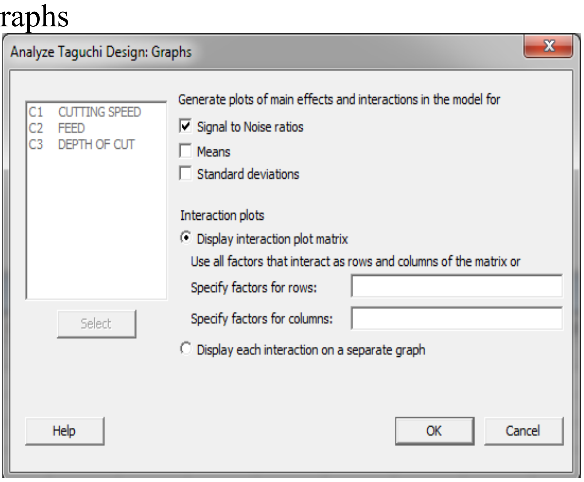
	C1	C2	C3	C4
	cutting speed	feed rate	depth of cut	surface roughness
1	800	80	0.5	3.253
2	800	100	1.0	2.853
3	800	120	1.5	3.826
4	800	140	2.0	1.773
5	1000	80	1.0	3.280
6	1000	100	0.5	3.295
7	1000	120	2.0	2.358
8	1000	140	1.5	3.173
9	1200	80	1.5	2.662
10	1200	100	2.0	3.954
11	1200	120	0.5	2.586
12	1200	140	1.0	3.152
13	1400	80	2.0	2.998
14	1400	100	1.5	2.946
15	1400	120	1.0	3.016
16	1400	140	0.5	2.184

Fig – Observed Surface Roughness

SURFACE ROUGHNESS

Stat – DOE – Taguchi - Analyze Taguchi Design – Select Responses

Graphs



Analyze Taguchi Design: Graphs

C1 CUTTING SPEED
C2 FEED
C3 DEPTH OF CUT

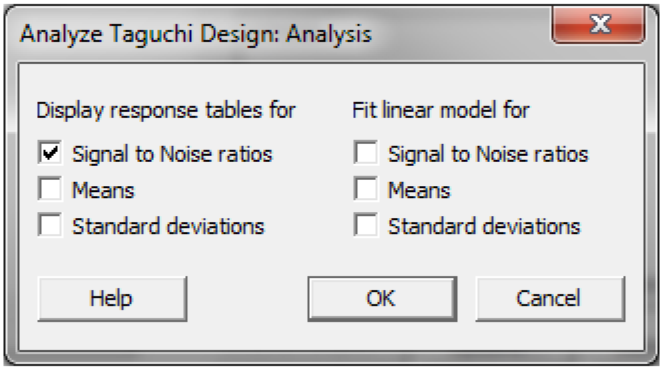
Generate plots of main effects and interactions in the model for

☑ Signal to Noise ratios
☐ Means
☐ Standard deviations

Interaction plots

● Display interaction plot matrix
Use all factors that interact as rows and columns of the matrix or
Specify factors for rows:
Specify factors for columns:
○ Display each interaction on a separate graph

Fig – Graphs Signal to Noise Ratio

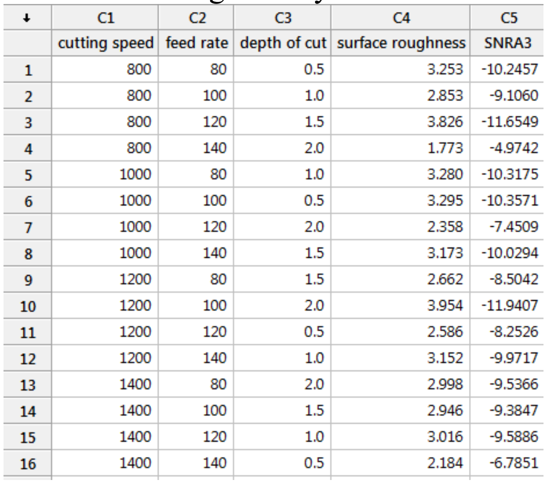


Analyze Taguchi Design: Analysis

Display response tables for
☑ Signal to Noise ratios
☐ Means
☐ Standard deviations

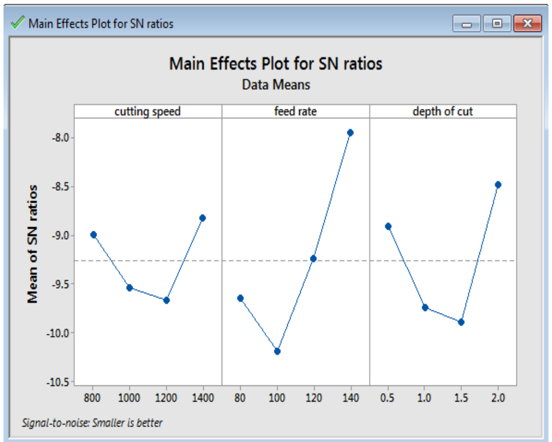
Fit linear model for
☐ Signal to Noise ratios
☐ Means
☐ Standard deviations

Fig - Analysis



	C1	C2	C3	C4	C5
	cutting speed	feed rate	depth of cut	surface roughness	SNRA3
1	800	80	0.5	3.253	-10.2457
2	800	100	1.0	2.853	-9.1060
3	800	120	1.5	3.826	-11.6549
4	800	140	2.0	1.773	-4.9742
5	1000	80	1.0	3.280	-10.3175
6	1000	100	0.5	3.295	-10.3571
7	1000	120	2.0	2.358	-7.4509
8	1000	140	1.5	3.173	-10.0294
9	1200	80	1.5	2.662	-8.5042
10	1200	100	2.0	3.954	-11.9407
11	1200	120	0.5	2.586	-8.2526
12	1200	140	1.0	3.152	-9.9717
13	1400	80	2.0	2.998	-9.5366
14	1400	100	1.5	2.946	-9.3847
15	1400	120	1.0	3.016	-9.5886
16	1400	140	0.5	2.184	-6.7851

Table – Results of S/N Ratio

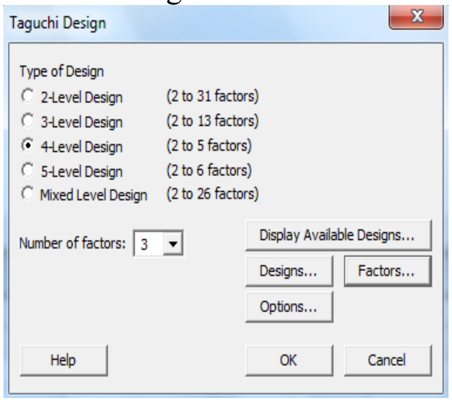


Graph - Effect of machining parameters on Surface Roughness for S/N ratio for Smaller is better

Response Table for Signal to Noise Ratios Smaller is better

OPTIMIZATION OF MRR USING TAGUCHI METHOD

Select 4-Level Design and No. of factors - 3

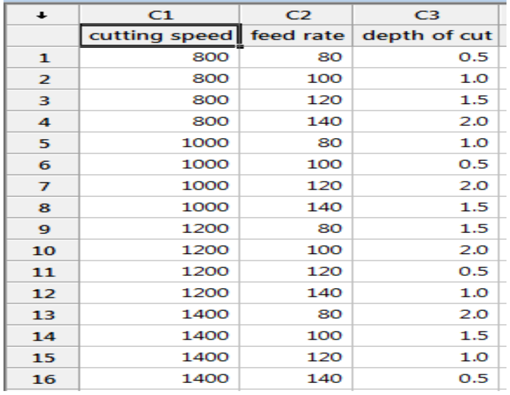


Taguchi Design

Type of Design
- ○ 2-Level Design (2 to 31 factors)
- ○ 3-Level Design (2 to 13 factors)
- ● 4-Level Design (2 to 5 factors)
- ○ 5-Level Design (2 to 6 factors)
- ○ Mixed Level Design (2 to 26 factors)

Number of factors: 3

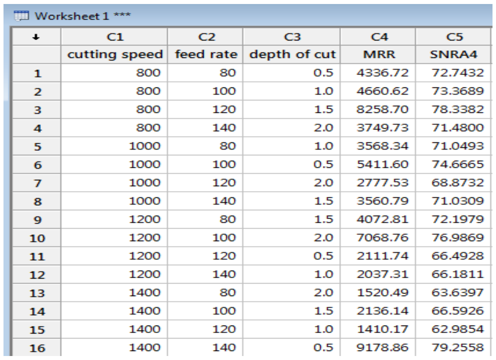
Fig – 4-Level Design 3 Factors



↓	C1	C2	C3
	cutting speed	feed rate	depth of cut
1	800	80	0.5
2	800	100	1.0
3	800	120	1.5
4	800	140	2.0
5	1000	80	1.0
6	1000	100	0.5
7	1000	120	2.0
8	1000	140	1.5
9	1200	80	1.5
10	1200	100	2.0
11	1200	120	0.5
12	1200	140	1.0
13	1400	80	2.0
14	1400	100	1.5
15	1400	120	1.0
16	1400	140	0.5

Fig – Arrangement of L16 orthogonal array for given parameters

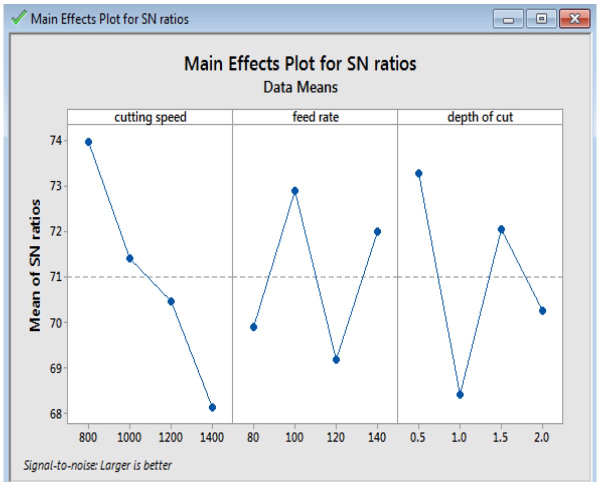
MRR



Worksheet 1 ***

↓	C1	C2	C3	C4	C5
	cutting speed	feed rate	depth of cut	MRR	SNRA4
1	800	80	0.5	4336.72	72.7432
2	800	100	1.0	4660.62	73.3689
3	800	120	1.5	8258.70	78.3382
4	800	140	2.0	3749.73	71.4800
5	1000	80	1.0	3568.34	71.0493
6	1000	100	0.5	5411.60	74.6665
7	1000	120	2.0	2777.53	68.8732
8	1000	140	1.5	3560.79	71.0309
9	1200	80	1.5	4072.81	72.1979
10	1200	100	2.0	7068.76	76.9869
11	1200	120	0.5	2111.74	66.4928
12	1200	140	1.0	2037.31	66.1811
13	1400	80	2.0	1520.49	63.6397
14	1400	100	1.5	2136.14	66.5926
15	1400	120	1.0	1410.17	62.9854
16	1400	140	0.5	9178.86	79.2558

Table – Results of S/N Ratio



Graph - Effect of machining parameters on MRR for S/N ratio for Larger is better

Response Table for Signal to Noise Ratios Larger is better

CONCLUSION

Different experiments are conducted to optimize the process parameters to improve the surface finish quality and material removal rate of Aluminum alloy 2024. A series of experiments aredone by varying the milling parameters cutting speed, feed rate and depth of cut considering L16 orthogonal array by Taguchi Method. The optimization is done for least surface roughness and high material removal rates.

The experiment has been done with process parameters feed rate 80mm/min, 100mm/min, 120mm/min, 140 mm/min, spindle speeds are 800rpm, 1000rpm, 1200rpm, 1400rpm, and depth of cut 0.5mm, 1mm, 1.5mm and 2mm. Optimization is done by taguchi method using Minitab 17 software.By observing the experimental results and by optimizing the parameters, the following conclusions can be made:

- To get better surface finish the optimized parameters are cutting speed – 1400rpm, feed rate – 140mm/min, Depth of Cut – 2mm.
- To get high MRR the optimized parameters are cutting speed – 800rpm, feed rate – 100mm/min, Depth of Cut – 0.5mm.

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