Multi Response Optimization of CNC Turning of Aluminum alloy (AA-1199) by using Grey Relational Analysis

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Abstract - *An abstract summarizes, in one paragraph (usually), the major aspects of the entire paper in the following prescribed sequence. The abstract of your paper must 250 words or less. This electronic document is a "live" template. The various components of your paper [title, text, heads, etc.] are already defined on the style sheet, as illustrated by the portions given in this document. Do not use special characters, symbols, or math in your title or abstract. The authors must follow the instructions given in the document for the papers to be published. This template, modified in MS Word 2007 and saved as a "Word 97-2003 Document (Size 10 & Italic , cambria font) In a manufacturing industry, economy of machining operation plays a key role in today's market. For any manufacturing process and particularly , in process related to CNC Turning the correct selection of manufacturing conditions is one of the most important aspects to take into consideration. This work investigates the effect and parametric optimization of process parameters of CNC Turning of AA-1199 aluminum alloy, using Grey Relational analysis. The input parameters considered are Spindle speed, Tool feed rate and depth of cut are optimized with consideration of Multi response characteristics including Surface roughness and Material removal rate. A well designed experimental scheme is used to reduce the total no of experiments. S/N Ratios associated with observed values in the experiments are determined by which factor is most affected by the responses. these experiments generate the output responses such as SR and MRR. The objective of optimization is to attain maximum MRR and minimum SR. Taguchi L9 orthogonal array has been used to design the combinations of parameters for the experiments. The machining experiments are performed on CNC machine. The Material removal Rate is checked by Weighing Machine and SR is checked by Profilometer. MINITAB software is used for finding the optimal values from the experimental values. firstly after finding the optimal values, graph for different parameters(spindle speed , tool feed and depth of cut)of mains and Signal to Noise ratio is plotted. Signal to Noise ratio is used according to response (output) that means if we want to find S/N ratio for MRR then S/N ratio larger is better and SR smaller is better. ANOVA is performed to get contribution of each parameter on the performance characteristics. The application of this technique converts the multi response variable to a single response grey relational grade and thus simplifies the optimization procedure.*

Key Words: *SR, MRR, TAGUCHI, ORTHOGONAL, GRA,ANOVA.*

1.INTRODUCTION

Turning is a machining process in which the work piece is rotated on the Lathe chuck and a cutting tool is fed into it radially, axially or both the ways simultaneously to give required (usually cylindrical surfaces). The axis of the cylindrical surface generated is often parallel work piece axis, while feed rate is given axial to the machine spindle. Once the cutting starts, the spindle speed and other cutting parameters will remain constant, the tool and work piece will remain in contact during the time the surface is being turned. At the same time, the cutting Spindle speed and cut dimensions will be constant when a cylindrical surface is being turned. Turning can be done manually, in an conventional version of lathe, which regularly needs continuous superintendence by the operator, or by employing a Computer-controlled (CNC) and automated lathe which does not require much supervision.. Turing can be of various types- straight turning, taper turning, profiling or external grooving. and can be used to produce material profiles like straight, conical, curved, or grooved work pieces. Each group of work piece materials has a predefined set of tool angles that ensure optimum turning performance. In turning, process parameters like cutting tool geometry and materials, depth of cut, feed rate, number of passes, spindle speed and use of cutting fluids will impact the costs, MRRs, cutting forces, tool life and other performance parameters like the surface roughness, the degree circular and dimensional deviations of the product.

1.1 Literature review

Lin C[1] studied taguchi method with grey relational analysis for optimizing turning operations with multiple performance characteristics. A grey relational grade obtained from the grey relational analysis is used to solve the turning operations with multiple performance characteristics. Optimal cutting parameters can then be determined by the Taguchi method using the grey relational grade as the performance index. Tool life, cutting force, and surface roughness are important characteristics in turning. Using these characteristics, the cutting parameters, including cutting speed, feed rate, and depth of cut are optimized in the study. Experimental results have been improved through this approach. **Kumar et al.[2]** Made an attempt to access the influence of machine of GFRP composites design of experiments (full factorial design) concept had been used for

experimentation. The factor considered were cutting speed, work piece, fiber orientation angle, depth of cut, and feed rate. A procedure had been developed to asses and optimization the chosen factor to attain minimum surface roughness by incorporating: (1) Response table and response graph. (11) Normal probability plot, (111) Interaction graphs (1v) Analysis of variance (ANOVA) technique. **Jha and Shahabadkar[3]** conducted research to utilize Taguchi methods to optimize the material removal rate for machining operation by using aluminum samples as work-piece. It was found that depth of cut has significant role in producing higher MRR. The optimal results was verified through conformation experiments with minimum number of trials as compared with full factorial design. **Vishnu et al.[4]** conducted experimental study to optimize the effect of cutting parameters on surface roughness of Al alloy 6351 by Taguchi technique. The cutting parameters selected was such as cutting speed , feed, depth of cut and coolant flow, L9 orthogonal array was used for experimentation. It was found that S/N ratio value of verification test was within the limits of the predicted value and the objective of the work was fulfilled.**Kumar P.[5],** investigated the improvement in the material removal rate of electrochemical machining. Experimental MRR has been calculated for different electrolytes condition on aluminium and stainless steel. The experimental results indicate that by using sea water as an electrolyte in electrochemical machining on aluminium alloy and steel alloy gives better MRR.

1.2 Material & Method

The experiments were performed on CNC Lathe machine MCL 10. In this experimentation the work piece material was AA-1199 aluminum alloy. The length and diameter of each specimen was 350mm and 30 mm respectively

Fig -1: CNC lathe machine mcl10

Table 1. Input parameters and their levels

Control factors	Factor levels		
	Level-1	Level-2	Level-3
Spindle Speed (rpm)	1100	1300	1500
Tool Feed (mm/min)	0.15	0.25	0.35
Depth of cut (mm)	0.3	0.5	0.7

Table 2. Orthogonal array for the experiment

Exp N	Spindle speed(rpm)	Feed rate (mm/min)	Depth of cut(mm)
1	1100	0.15	0.3
2	1100	0.25	0.5
3	1100	0.35	0.7
4	1300	0.15	0.5
5	1300	0.25	0.7
6	1300	0.35	0.3
7	1500	0.15	0.7
8	1500	0.25	0.3
9	1500	0.35	0.5

2. EXPERIMENT CONDUCT

The experiment was conducted on CNC Lathe MCL10. The work piece used was Aluminum Alloy AA-1199 of Diameter 30mm and length 350mm. The high Speed steel Tool was used for the cutting of the material. Experimental was performed as per orthogonal setup for nine times. Aluminum alloy AA-1199 will be used as a work-piece material. It is silverfish white metal that has a strong resistance to corrosion and like gold, is rather malleable. It is a relatively light metal compared to metals such as steel , Nickel, brass and copper. It is easily machinable and can have wide variety of surface finishes. It also has good electrical and thermal conductivities and is highly reflective to heat and light.

Table 3. Chemical Composition of AA-1199

Cu	Si	Mn	Fe	Mg	Ti	Zn	V	Ga+Bi+Pb+Zr	AL
0.006	0.06	0.002	0.006	0.006	0.002	0.006	0.005	0.005	99.9

Table 4. Mechanical and Thermal properties of AA-1199

Tensile Strength (MPa)	Specific garvity	Poisson's ratio	Elastic Modulus (GPa)	Density (g/cm3)	Thermal Conductivity at 25°C (W/m-K)
230-570	2.7	0.33	70-80	2.6-2.8	243

Table 5. Experimental observations for SR & MRR

EN.	Spindle speed (rpm)	Tool Feed rate (mm/min)	Depth of cut(mm)	Surface roughness (μm)	MRR (mm3/min)
1	1100	0.15	0.3	1.1426	1786.44
2	1100	0.25	0.5	1.2565	2188.91
3	1100	0.35	0.7	1.4308	2935.85
4	1300	0.15	0.5	1.3599	2154.60
5	1300	0.25	0.7	1.3789	2749.98
6	1300	0.35	0.3	0.9944	3547.29
7	1500	0.15	0.7	1.5799	2175.90
8	1500	0.25	0.3	0.9770	2878.87
9	1500	0.35	0.5	1.2790	3438.56

3. RESULT AND ANALYSIS

The Average effect Response Table for raw data and S/N Ratios for SR are shown in Table below. From the Table 6 and 7 and on the basis of Ranks from the Tables, it has been analyzed that the parameter Depth of cut is the most significant factor which affects the SR.

Table 6. Response table for S/N Ratios for SR

Level	Spindle speed	Tool Feed	Depth of cut
1	-2.0842	-2.6002	-0.3023
2	-1.8040	-1.5239	-2.2636
3	-1.9693	-1.7334	-3.9893
Delta	0.2802	1.0763	2.9893
Rank	3	2	1

Table 7. Response table for means for SR

Level	Spindle speed	Tool Feed	Depth of cut
1	1.277	1.361	1.038
2	1.244	1.204	1.298
3	1.279	1.235	1.463
Delta	0.034	0.157	0.425
Rank	3	2	1

The Average effect Response Table for S/N ratio for MRR shown below. From the table 8 and on the basis of Rank, it has been analyzed that Tool Feed parameter plays a significant factor which affects the MRR.

Table 8. Response Table for S/N Ratios for MRR

Level	Spindle speed	Tool Feed	Depth of cut
1	67.07	66.15	68.41
2	68.82	68.26	68.07
3	68.89	70.36	68.30
Delta	1.82	4.21	0.34
Rank	2	1	3

The final results is Analyzed using ANOVA for identified the significant factor affecting the performance measure. The purpose of analysis of variance (ANOVA) is to determine which parameters significantly affect the quality characteristic. The analysis of variance is to identify the set of all independent variable (factors) that can potentially affect the value of response variable. The ANOVA for SR is taken at 95 % of confidence level. From table 7 below it is apparent that the P values of factor Depth of cut and factor

Tool feed is less than P=0.05. It means that these terms influence the model to a great extent. The most significant input factor is depth of cut for surface roughness.

**Table 9.** Analysis of variance Table for SR

Source	DOF	Seq SS	Adj SS	Adj MS	F	P
Spindle speed	2	0.002215	0.002215	0.001107	3.34	0.231
Tool Feed	2	0.041374	0.041374	0.020687	62.31	0.016
Depth of cut	2	0.275775	0.275775	0.137887	415.36	0.002
Error	2	0.000664	0.000664	0.000332		
Total	8	0.320027				

The ANOVA for MRR is taken at 95 % of confidence level. From table 8 it is apparent that the P values of factor spindle speed, tool feed and depth of cut are less than P=0.05. It means that these terms influence the model to a great extent. The most significant input factor is tool feed for material removal rate(MRR).

Table 10. Analysis of Variance Table for MRR

Source	DOF	Seq SS	Adj SS	Adj MS	F	P
Spindle speed	2	542058	542058	271029	671.97	0.001
Tool Feed	2	2421728	2421728	1210864	3002.12	0.000
Depth of cut	2	34979	34979	17490	43.36	0.023
Error	2	807	807	403		
Total	8	2999571				

In the Experiment analysis, the main effect Plot for Means Fig 2 is used to find the optimal parameters for Minimum SR. So the optimum parameter combination for the minimum surface roughness is Second level of spindle speed(1300 rpm), second level of tool feed(0.25mm/min) and first level of depth of cut(0.3mm), i.e.(A2B2C1).
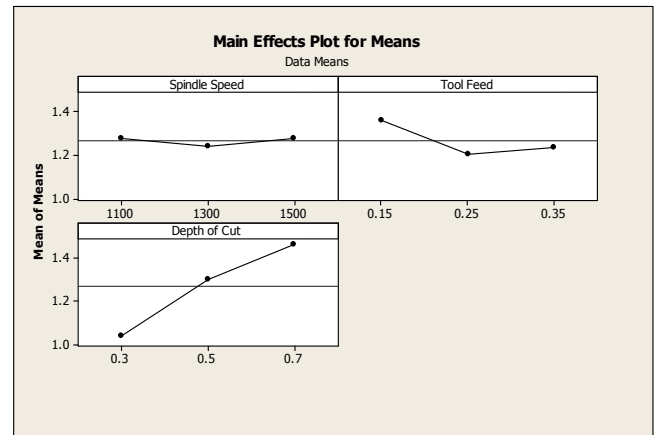
Fig 2. Main effects plot for Means for SR
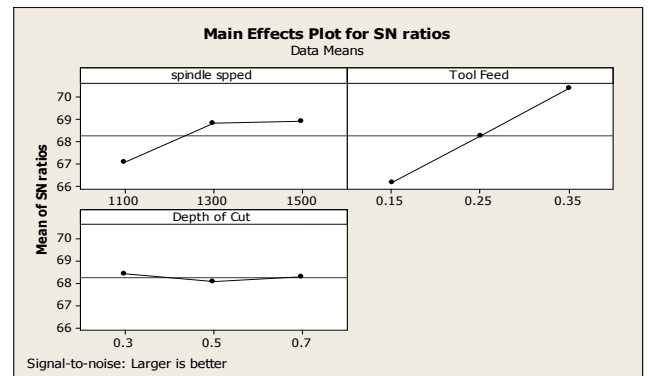
Fig -1: Main Effects Plot for S/N Ratios for MRR

The Main effects plot for S/N ratios fig 3 is used to optimized the parameters for Higher Material removal Rate(MRR).The optimum parameters combination for Higher Material Removal rate(MRR) for the above study is third level of spindle speed(1500 rpm), third level of tool feed(0.35mm/min.) and first level of depth of cut(0.3mm),i.e.($A_3B_3C_1$) .

3.1 Multi-response optimization using grey relational analysis

GRA is used to convert multi response results into a single response or objective. The aim is to identify the optimal combination of process parameters that minimize the SR and maximize the MRR. The Normalized S/N ratio for SR and MRR in table 11 is calculated with the help of relation below.
For maximum material removal rate (MRR) :
For minimum surface roughness (SR) :

$$\frac{Y_{ij} - \min(Y_{ij}, i = 1,2,3,\ldots,n)}{\max(Y_{ij}, i = 1,2,3,\ldots,n) - \min(Y_{ij}, i = 1,2,3,\ldots,n)}$$

Grey Relational coefficient in Table 11 is calculated with the help of relation,

$$\xi\,(k) = \frac{\Delta\min + \zeta\,\Delta max}{\Delta o + \zeta\,\Delta max}$$

Here $\xi(k)$ is identified coefficient and value of $\xi\,(k) = 0.5$ is generally used.

The Grey Relational Grade is calculated by averaging the Grey relational coefficient corresponding to each performance characteristics in Table 11.

Table 11. Grey Relational Grade

Run	Spindle speed(rpm)	Tool Feed(mm/min)	Depth of cut(mm)	Normalized S/N ratios		Grey Relational coefficient		Grey Relational Grade	Rank
				SR	MRR	SR	MRR		
1	1100	0.15	0.3	0.7253	0	0.6454	0.3333	0.4893	5
2	1100	0.25	0.5	0.5364	0.2285	0.5188	0.3932	0.456	7
3	1100	0.35	0.7	0.2473	0.6527	0.3991	0.5901	0.4946	4
4	1300	0.15	0.5	0.3649	0.2090	0.4404	0.3872	0.4138	8
5	1300	0.25	0.7	0.3333	0.5472	0.4285	0.5247	0.4766	6
6	1300	0.35	0.3	0.9711	1	0.9453	1	0.9726	1
7	1500	0.15	0.7	0	0.2211	0.3333	0.3909	0.3621	9
8	1500	0.25	0.3	1	0.6203	1	0.5683	0.7841	3
9	1500	0.35	0.5	0.977	0.9382	0.9560	0.8899	0.9229	2

4. CONCLUSIONS

1. The surface roughness is mainly affected by the depth of cut. With the increase in depth of cut surface roughness increases and with increase in tool feed , the surface roughness decreases, but with further increase in tool feed it again started increasing. Spindle speed has a very little effect on surface roughness for present study.

2. From ANOVA analysis it has been found that depth of cut and tool feed are the significant factors affecting the surface roughness.

3. The material removal rate is mainly affected by tool feed rate. With the increase in tool feed rate material removal rate increases and it also increase with increase in spindle speed. Depth of cut has no effect on material removal rate for the present study.

4. From ANOVA analysis its has been found that tool feed rate is the most significant factors affecting the material removal rate.

5. Grey relational analysis were applied in this work for multi response characteristics such as MRR and SR. And the optimal parameter combination for minimum SR and higher MRR was determined as A_2 (spindle speed, 1300rpm), B_3 (tool feed, 0.35 mm/min) and C_1 (depth of cut, 0.3 mm), i.e $(A_2 B_3 C_1)$.

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