Optimization of Cutting Tool and Cutting Parameters in CNC Turning of Aluminum Alloy 6063 through using the Taguchi method

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Abstract - *This paper presents the mathematical modelling and parametric optimization on material removal rate, Machining Time, and surface roughness in turning operation of AA6063 steel with cemented inorganic compound coated atomic number 74 insert tool underneath different cutting parameters. The improvement of grey relational grade from initial parameter combination (a3–be–c3) to the optimal parameter combination (a1–b1–c1) is found to be 0.520 using grey relational analysis coupled with Taguchi method for simultaneous optimization of responses.*

Keywords Centre lathe, AA6063 alloy steel, Material removal rate, Machining time, Surface Roughness, Carbide tools.

1. INTRODUCTION

In order to settled bridge between quality and productivity the current experimental study high light centre lathe machine method parameters to produce sensible surface end still as high material removal rate. Surface end and material removal rate has been known as quality attributes and square measure assumed to be directly associated with productivity.

This experimental study presents an efficient approach for the improvement of shaping machine exploitation MINITAB 18 and Taguchi Technique in varied condition. The knowledge concerning machining of inauspicious cutting materials is insufficient and difficult. So AN experimental study needs to be conducted to come back out with an optimum outcome. Out of the different parameters that may be considered because the producing goal, the material removal rate (MRR) was thought of for this work because the factor directly affects the value of machining and therefore the machining hour rate.

The machining parameters specifically cutting speed, feed rate and depth of cut were thought of. The objective was to seek out the optimized set of values for maximizing the MRR by Taguchi technique. Therefore the current work is targeted on finding the optimum parameters combination of cutting speed, feed and depth of cut for maximizing the rate of material removal during machining. The machining parameters elite for a turning operation is a crucial procedure so as to realize high performance.

Taguchi methods developed by Genichi Taguchi improve the quality of manufacturing roots are recently applied to the field of engineering, biotechnology, marketing and advertising. The Taguchi method is a very powerful carrying of experimental design, the main aim of the Taguchi methods is to produce an optimum result of analyzing the statistical data which have been given as input function. This technique permits restricted no of experimental runs by utilizing a well-balanced experimental style known as orthogonal array style and signal to noise magnitude relation.

Common US Grades of Stainless Steel

In general, the selection of a stainless steels are based on

Corrosion resistance

Fabrication characteristics

Availability

Mechanical properties over a specific temperature rangesProduct cost

Since stainless steel is corrosion resistant, it maintains its strength at high temperatures

TYPE304: The most frequently specified austenitic (chromium-nickel stainless class) stainless steel, accounting for more than 50 % of the stainless steel production in the world.

TYPE316: Primary solid solution (chromium-nickel untarnished class) stainless-steel containing 2 Chronicles - three nada metallic elements (whereas kind 304 stainless-steel has none). The inclusion of metallic element provides kind 316 stainless-steel, greater resistances to numerous sorts of deterioration.

TYPE409: Ferrite (plain metallic element stainless-steel category) stainless-steel suitable for prime temperature. This grade has rock bottom metallic element content of all untarnished steels and so is that the least high-ticket.

TYPE410: the foremost wide used martensitic (plain metallic element untarnished category with exceptional strength) stainless-steel, facultative a high level of strength advised by the martensitic stainless-steel. It's a heat treatable grade of low cost that is appropriate for non-severe corrosion applications.

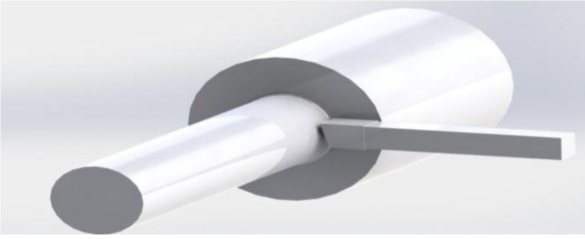

Fig.1. Rendered picture of turning operation (Drawn in Solid Works 2013)

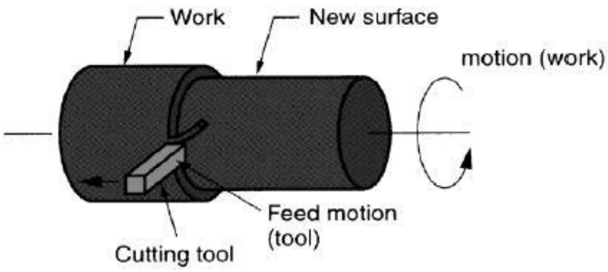

Fig.2. Turning operation [40]

Machining could be a part of the manufacture business of the many metal product, however it can even be used on materials like wood, plastic, ceramic, and composites. Machining is that the most significant of the producing processes. Machining is outlined because the method of removing material from a work piece within the type of chips. The term metal cutting is employed once the material is metallic.

Turning could be a type of machining, a material removal method, that is employed to make motion components by cutting away unwanted material.

3. Materials and Methods

Based on the properties and their application in the manufacturing industry the AA6063 Alloy steel materials of 20mm diameter and 150mm length rolled rod is used for this research work and the machining has been carried out with experimentation on centre lathe machine as shown in figure 1. For this study L9 OA experiments were used. The material removal8rate is calculated by using the Equation (1)[9]. MRR=$Wtb - Wtat*\rho$ (1) Where Wtb, Wta - Weight of workpiece before and after machining in mg t- Machining Time in min, ρ- Density of the steel.

3.1 Work Material

The experiments were performed with turning of material AA6063-T6. The bars used are of diameter 19 mm and length 65 mm.Following table shows the chemical and mechanical composition of selected material.

Table 3.1.1 Mechanical properties of AA6063-T6 aluminium alloy

Density (kg/mm^3)	Melting point (degree centigrade)	Ultimate tensile strength (kgf/mm^2	Yield strength (kgf/mm^2)	Hardness (HV)
2,600-2,800	660	1.8-2.6	1.4-12	124

Table 3.1.2 Chemical compositions of AA6063-T6 aluminium alloy

Element	Cu	Mg	Si	Fe	Mn	Zn	Ti	Cr	Al
%of compositions	**0.01**	**0.64**	**0.7**	**0.17**	**0.11**	**0.06**	**0.03**	**0.01***	**Remaining**

3.1.2. Machine Tool

The experiment was carried out on a 2 axis XL Turn bench Top CNC trainer Lathe machine (Fanuc series) of MTAB Engineers (P) Ltd, India.

3.1.3 Cutting Tools and Tool Holders

The cutting tool selected for machining AA6063-T6 is carbide insert tool bearing ISO catalog number DCMT 11T304 NU. The tool holder taken for Carbide inserts is of ISO CODE No SCLCR 1212F09.

4. RESULTS AND DISCUSSION

Table 4.1. Taguchi Analysis: Main effect plot for means for MRR

SPINDLE SPEED	DOC	FEED RATE	Material Removal Rate	Machine Time (Mt)	Surface Roughness (Ra)	SNRA2	MEAN2
2000	0.4	125	3141.59	0.000160	0.462	69.942997	3141.5927
2000	0.6	140	5277.88	0.000143	0.579	74.449183	5277.8757
2000	0.8	160	8042.48	0.000125	0.667	78.107797	8042.4772
1500	0.4	140	3518.58	0.000190	0.811	70.927358	3518.5838
1500	0.6	160	6031.86	0.000167	1.241	75.609022	6031.8579
1500	0.8	125	6283.19	0.000213	0.778	75.963597	6283.1853
1000	0.4	160	4021.24	0.000250	2.542	72.087197	4021.2386
1000	0.6	125	4712.39	0.000320	1.657	73.464823	4712.389
1000	0.8	140	7037.17	0.000286	2.57	76.947958	7037.1675

4.2 Taguchi Analysis: Main effect plot for S/N ratio for MRR

Analysis of Variance (ANOVA):

The analysis of variance estimates the significance of machining parameters on material removal rate. The significance of process parameters are identified by comparing α=0.05 level of 95% confidence level with p-value column, if p-value is less than 0.05 then the process parameter is said to be significant and p value is more than 0.05, then the process parameters is said to be insignificant and also ANOVA table gives the influencing parameters on response [9]. The analysis of variance presents the significance of process parameter on response variable for AA6063 material, From Table 1 it is conclude that rotational speed and depth of cut , feed rate is insignificant, also from the F- test value can conclude that rotational speed is most influencing parameters followed by feed rate ,rotational speed and.

The analysis of variance for AA6063 steel materials are presents the significance of process parameter on response variable, From Table 1 it can be seen that rotational speed insignificant and feed rate and depth of cut has significant effect on material removal rate, also from the F- test value can conclude that depth of cut is most influencing parameters followed by feed rate and rotational speed.

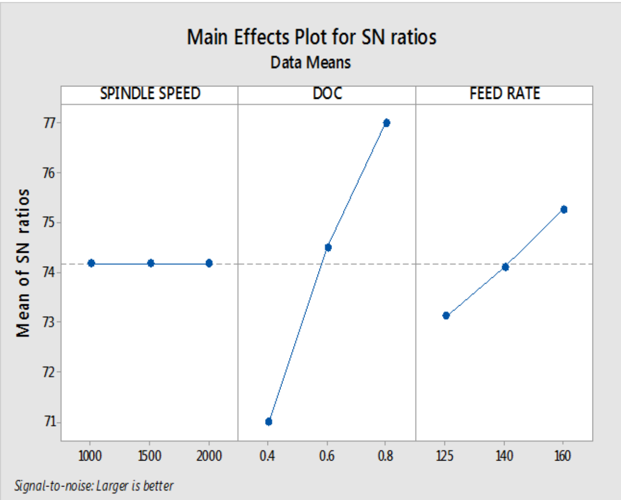

Fig. 4.2.1: Main effect plot for S/N ratios:MRR

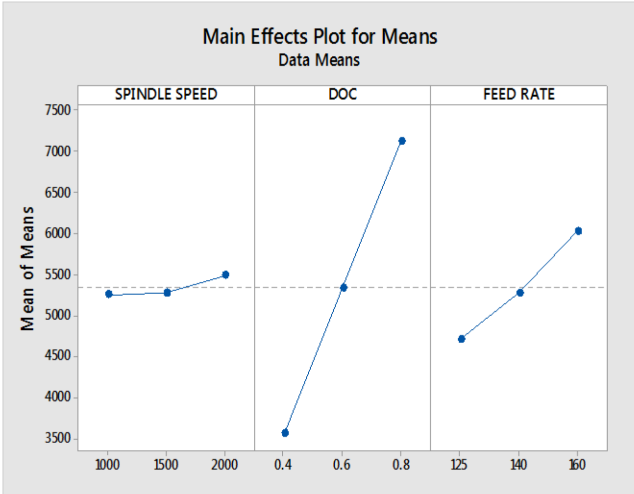

Fig. 4.2.2: Main effect plot for Means of MRR

4.2.1 Taguchi Analysis: Material Removal Rate versus SPINDLE ... FEED RATE

Result and Analysis

Minitab 17 software is used in the experimental work for the analysis. This software inputs and analyses the experimental data & gives the calculated results of signal-to-noise ratio. The objective of this experiment is to minimize machining time and maximize the MRR in turning optimization. The impact of various method parameters on MRR and machining time area unit calculated and premeditated the graphs from one level to a different. In this experiment, 3 totally different tools area unit used thus, the analysis is completed on the premise of tool material.

4.2.2 Response Table for Signal to Noise Ratios Larger is better

Level	SPINDLE SPEED	DOC	FEED RATE
1	74.17	70.99	73.12
2	74.17	74.51	74.11
3	74.17	77.01	75.27
Delta	0.00	6.02	2.14
Rank	3	1	2

As MRR is the “larger is better” type quality characteristic, it can be seen from Figure 1 that the first Level of Spindle speed (A3), second level of depth of cut (B1) feed rate (C2) provide maximum value of MRR.

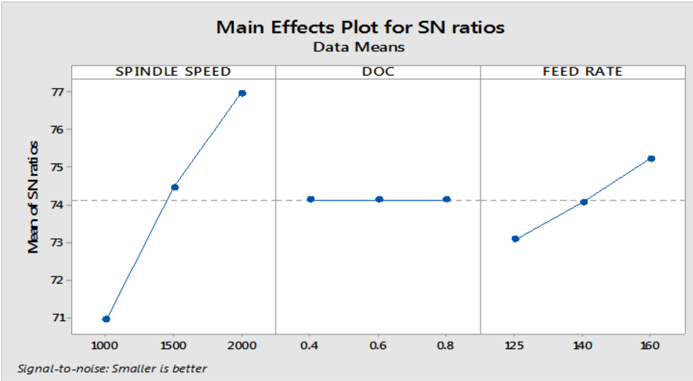

Fig. 4.3.1: Main effect plot for S/N ratios: MRR: MT

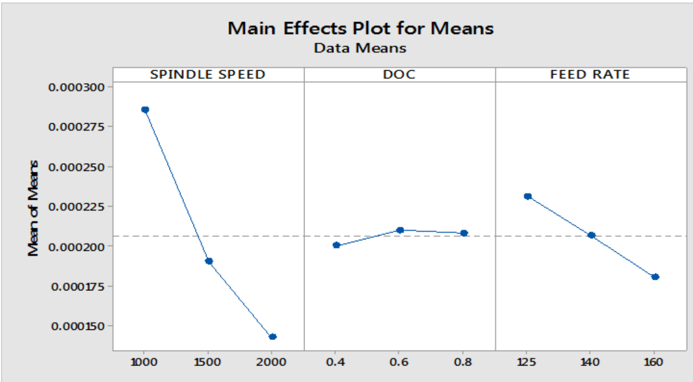

Fig. 4.3.2: Main effect plot for Means: MT

Taguchi Analysis: Machine Time (Mt) versus SPINDLE ... C, FEED RATE

4.3.1 Response Table for Signal to Noise Ratios Smaller is better

Level	SPINDLE SPEED	DOC	FEED RATE
1	70.94	74.12	73.08
2	74.46	74.12	74.06
3	76.96	74.12	75.22
Delta	6.02	0.00	2.14
Rank	1	3	2

From the table 5.4.2 delta values it assigns the rank to each which is having more influence on the mean of machining time. From the results S/N ratio also it is observed that spindle speed is the dominant factor for machining time.

From the above graph, the optimum values for the machining time are (a): spindle speed (b): feed rate (c): Depth of cut .The grater S/N ratio values are considered for the smaller the- better criteria. Higher S/N ratio value gives the better result for both minimizing and maximizing response so always higher S/N ratio value are taken

As Machining Time is the "smaller the- better " type quality characteristic, it can be seen from Figure 5.4.2 that the first Level of Spindle speed (A1), second level of depth of cut (B3) feed rate (C2) provide minimum value of machining time.

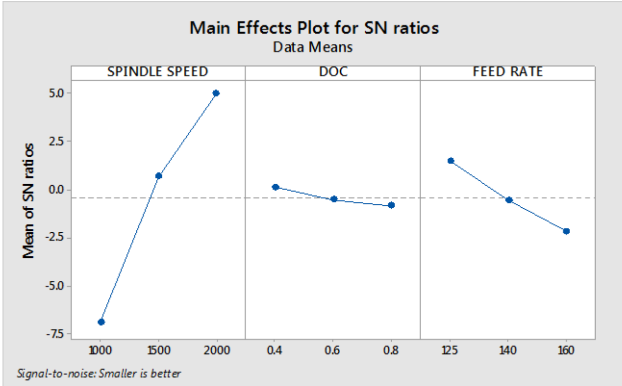

Fig. 4.3.4: Main effect plot for S/N ratios: SR

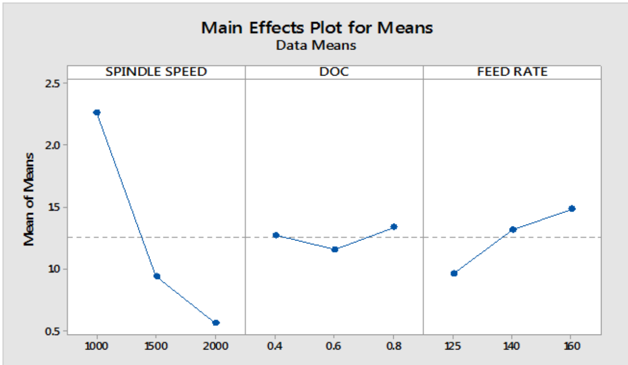

Fig. 4.3.5: Main effect plot for Means: SR

4.3.2 Taguchi Analysis: Surface Roughness (Ra) versus ... D, DOC, FEED RATE

4.3.2 Response Table for Signal to Noise Ratios Smaller is better

Level	SPINDLE SPEED	DOC	FEED RATE
1	-6.8962	0.1411	1.5004
2	0.7082	-0.5052	-0.5442
3	4.9904	-0.8336	-2.1538
Delta	11.8866	0.9747	3.6542
Rank	1	3	2

From the table 5.4.2 delta values it assigns the rank to each which is having more influence on the mean of surface roughness. From the results S/N ratio also it is observed that spindle speed is the dominant factor for machining time.

From the above graph, the optimum values for the surface roughness are (a): spindle speed (b): feed rate (c): Depth of cut .The grater S/N ratio values are considered for the smaller the- better criteria. Higher S/N ratio value gives the better result for both minimizing and maximizing response so always higher S/N ratio value are taken

As is the surface roughness "smaller the- better " type quality characteristic, it can be seen from Figure 5.4.3 that the first Level of Spindle speed (A1), second level of feed rate (C2)and depth of cut (B3) provide minimum value of surface roughness.

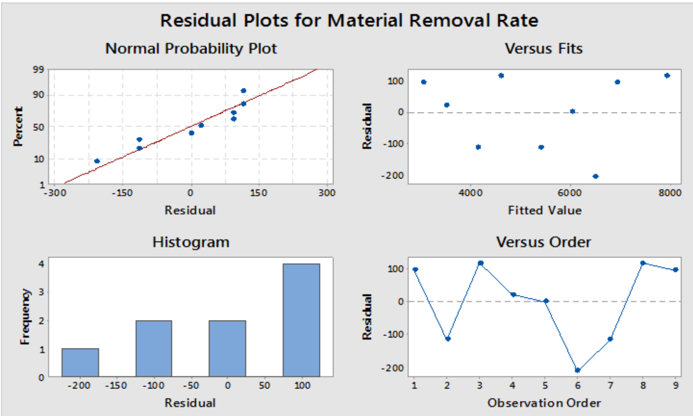

Fig. 4.3.1: Residual Plot of Material Removal Rate

4.4 Analysis of Variance (ANOVA)

In this work, the response output for the given input data has been obtained in the form of regression equations (by RSM) using MINITAB 18.0. It is possible to obtain the output response in the form of equations for the given input data Taguchi method cannot determine the effect of individual parameters on the whole method therefore analysis of variance is employed to work out the share contribution of a private parameter provided in MINITAB 18.

General Linear Model: Material Removal Rate versus ... EED RATE, DOC

Analysis of Variance

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
SPINDLE SPEED	2	97380	0.45%	97380	48690	1.00	0.500
FEED RATE	2	2629263	12.04%	2629263	1314631	27.00	0.036
DOC	2	190154	87.07%	1901543	9507719	195.27	0.005
Error	2	97380	0.45%	97380	48690		
Total	8	2183946	100.00%				

Table 4.4 ANOVA result for MRR

Model Summary

S	R-sq	R-sq(adj)	PRESS	R-sq(pred)
220.658	99.55%	98.22%	1971947	90.97%

It is clear from above table that the effect of Depth of cut Feed rate and spindle speed and material removal rate (MRR) is 87.07%, 12.04% and 0.45% respectively.

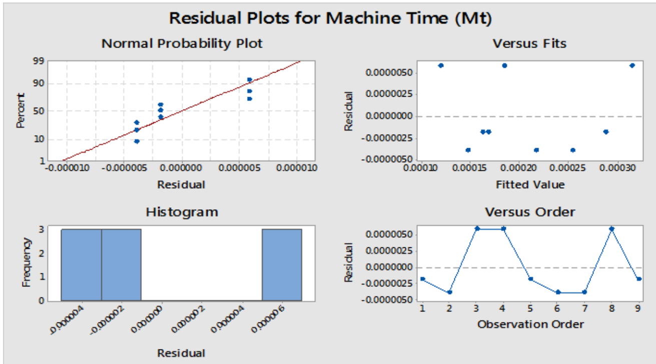

Fig. 4.5.1: Residual Plot of Machining Time

4.5.1 General Linear Model: Machine Time (Mt) versus ..., FEED RATE, DOC

Analysis of Variance

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
SPINDLE SPEED	2	0.00	88.40%	0.00	0.00	199.22	0.005
FEED RATE	2	0.	10.71%	0.00	0.00	24.14	0.040
DOC	2	0.0	0.44%	0.0	0.00	1.00	0.500
Error	2	0.0	0.44%	0.0	0.0		
Total	8	0.0	100.00%				

Table 5.5.1 ANOVA result for Machining Time

Model Summary

S	R-sq	R-sq(adj)	PRESS	R-sq(pred)
0.0000089	99.56%	98.23%	0.0000000	91.01%

It is clear from above table that the effect of spindle speed, Feed rate and Depth of cut on machine time (MT) is 88.40%, 10.71% and 0.44% respectively are recommended to obtain better Machining Time (MT) for the specific range.

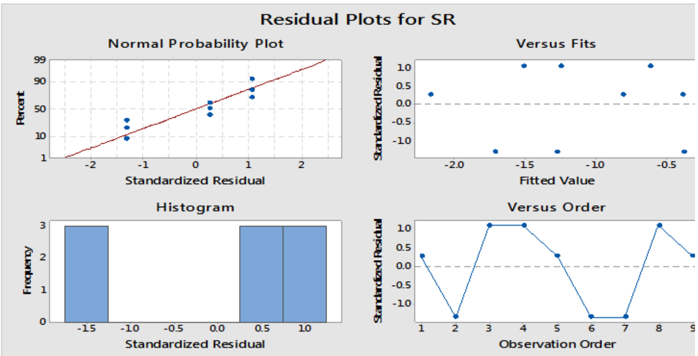

Fig. 4.5.2: Residual Plot of Surface Roughness.

4.5.2 General Linear Model: Surface Roughness (Ra) versus ... ED RATE, DOC

Analysis of Variance

Analysis of Variance for Transformed Response

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
SPINDLE SPEED	2	2.67408	87.07%	2.67408	1.33704	3157.23	0.000
DOC	2	0.09009	2.93%	0.09009	0.04504	106.36	0.009
FEED RATE	2	0.30612	9.97%	0.30612	0.15306	361.43	0.003
Error	2	0.00085	0.03%	0.00085	0.00042		
Total	8	3.07114	100.00%				

Model Summary for Transformed Response

S	R-sq	R-sq(adj)	PRESS	R-sq(pred)
0.0205788	99.97%	99.89%	0.0171511	99.44%

It is clear from above table that the effect of spindle speed, Feed rate and Depth of cut on surface roughness (SR) is 87.07%, 09.97% and 2.93% respectively are recommended to obtain for surface roughness. Out of all thee input process parameter spindle speed is most significant with respect to all process parameter and f value is 3157.23 for spindle speed.

4.5.3 Regression Analysis: Surface Roughness (Ra) versus ... EED RATE, DOC

It's used to investigate and model the relationship between a response variable and one or more predictors. Minitab provides least square, partial least square and logistic regression procedures. A multiple regression analysis was conducted on the tested data. Coefficients of the analysis of the regression model also supported linear relationships in the model.

Analysis of Variance

Table 4.5.3 Regression Analysis: Surface Roughness (Ra) versus ... EED RATE, DOC

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	3	4.66097	1.55366	10.46	0.014
SPINDLE SPEED	1	4.26895	4.26895	28.74	0.003
FEED RATE	1	0.38535	0.38535	2.59	0.168
DOC	1	0.00667	0.00667	0.04	0.841
Error	5	0.74265	0.14853		
Total	8	5.40361			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.385395	86.26%	78.01%	53.28%

5. CONCLUSIONS

This paper has presented an application of parameter design of the taguchi method in the optimization of turning operations in centre lathe machine. The following conclusions will be drawn supported the experimental results of this study:

1. Taguchi's robust orthogonal array design method is suitable to analyze the machining time (metal cutting) as well as material removal rate problem surface roughness.
2. It is additionally found that the various constant quantity style supported the Taguchi methodology provides a straightforward, systematic and efficient methodology for the optimization of the machining parameters.
3. It can be concluded that spindle speed and depth of cut are the main parameters among the three controllable factors (spindle speed, feed rate, and depth of cut) that influence material removal rate during CNC Milling machine.
4. As MRR is the "larger is better" type quality characteristic, it can be seen from Figure 1 that the first Level of Spindle speed (A3)1000rpm, second level of depth of cut (B1)0.4mm, feed rate (C2) 140mm/rev provide maximum value of MRR.
5. This experiment additionally suggests that the material removal rate is very influenced first by the feed rate so depth of cut followed by spindle speed. It is clear from analysis that the effect of Feed rate spindle speed and Depth of cut on material removal rate (MRR) is 41.47%, 37.11% and 21.42.68% respectively.

6. In turning for maximum material removal rate, It is clear that the effect of Depth of cut Feed rate and spindle speed on material removal rate (MRR) is 87.07%, 12.04% and 0.45% are recommended to obtain better material removal rate (MRR) for the specific range

7. It is clear from above table that the effect of spindle speed, Feed rate and Depth of cut on surface roughness (SR) is 87.07%, 09.97% and 2.93% respectively are recommended to obtain for surface roughness. Out of all thee input process parameter spindle speed is most significant with respect to all process parameter and f value is 3157.23 for spindle speed.

References

[1] Upinder Kumar Yadav, Deepak Narang&Pankaj Sharma Attri, "Experimental investigation and Optimization of machine parameters for surfaceroughness in CNC turning by Taguchi method", International Journal of Engineering Research and Application", vol. 2, Issue 4, pp 2060-2065., 2012

[2] Harish Kumar, Mohd. Abbas, Dr.Aas Mohammad &HasanZakirJafri, "Optimization of cutting parameters in CNC Turning", InternationJournal of Engineering Research and Applications", vol. 3, Issue 3, pp. 331-334, 2013.

[3] BalaRaju. J, Anup Kumar. J. Dayal Saran. P, C.S. Krishna Prasad Rao, —Application of Taguchi Technique for Identifying Optimum Surface Roughness in CNC end Milling Process, International Journal of Engineering Trends and Technology, Volume 2, pp. 103 – 110, March 2015.

[4] J.B.Shaikh, J.S.Sidhu., —Experimental Investigation and Optimization of Process Parameters in Turning of AISI D2 Steel using Different Lubricant||, International Journal of Engine

[5] Ramyasree Keerthi, Anitha Lakshmi Akkireddy., —To Investigate the Effect of Process Parameters on SurfaceRoughness of AISI 1045 Steel in Dry Machining with CBN Cutting Tool Using ANOVA||, Vol. 25, No.1, July 2015.

[6] Basim A. Khidhir, Waleed Al- Oqaiel, PshtwanMuhammed Kareem., Prediction Models by Response Surface Methodology for Turning Operation, American Journal of Modeling and Optimization, Vol. 3, No.1, pp. 1-6, 2015ering and Advanced Technology, Vol. 3, Issue 5, June 2014

[7] Krishankant, JatinTaneja, MohitBector and Rajesh Kumar, "Application of taguchi method for optimizing turning process by the effects of machining parameters," International journal of engineering and advanced technology, vol. 2, no. 1, October 2012.

[8] U. D. Gulhane, A.B. Dixit, P.V. Bane and G.S. Salvi, "Optimization of process parameters for 316L stainless steel using taguchi method and anova," International journal of mechanical engineering and technology, vol. 3, no. 2, pp. 67-72, May-August2012.

[9] L B Abhang, and M Hameedullah, "Optimization of machining parameters in steel turning operation by taguchi method," International conference on modeling optimization and computing, Procedia Engineering 38, 2012, pp. 40-48.

[10] M. Kaladhar, K. VenkataSubbaiah, Ch. Srinivasa and K. NarayanaRao, "Optimization of process parameters in turning of AISI202 austenitic stainless steel," ARPN journal of engineering and applied sciences, vol. 5, no. 9, September 2010.

[11] W.H. Yang, and Y.S. Tarng, "Design optimization of cutting parameters for turning operations based on the taguchi method," Journal of materials process technology 84, 2012, pp. 122-129.