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Optimization of Process Parameters in CNC Turning of Copper and Aluminium Alloy Using Taguchi Approach

Ruby Haldar[1], Santanu Duari[2]
[1, 2]Department of Mechanical Engineering, Techno International Newtown

Abstract: This paper manages the optimization level comparison of the metal copper (Cu) and aluminium (Al) bar by utilizing the Taguchi strategy with the orthogonal array (L_{27}) powerful plan. The yield of the improvement is from the turning of the copper and aluminium bar utilizing a CNC machine. Taguchi strategy is an adaptable strong plan procedure that is utilized in numerous ventures known for its high interaction quality, upkeep and advancing the nature of the item soundness. It is an incredible and proficient strategy for upgrading the exhibition of different mechanical assembling measures. The machining boundaries (speed, feed rate, depth of cut) of both the materials copper and aluminium is taken as a comparison for accomplishing the base surface roughness by utilizing the Taguchi strategy for DOE and ANOVA to accomplish the optimization level for the best quality item for minimal price in the manufacturing processes. Three level of parametric esteems have been picked as input parameters to get critical ideal yield results for the materials. In the wake of examining the information and ascertaining the signal to noise ratio (S/N) the last ideal levels of each input parameters are acquired to look at the best outcomes.
Keywords: Surface roughness, Taguchi method, CNC turning, Optimization.

I. INTRODUCTION

In the present tremendous populace with expansion in requests of different cutting edge innovations in this advanced world, it's vital to change the manufacturing processes whose principle point is to deliver excellent items with minimal expense and less support with an insignificant measure of endeavours and actual work. A large portion of the manufacturing industries is utilizing CNC machines for processing, turning, reaming, striking, and so on. The CNC machining with PC programming gives the steady, exact, and exact worth with no breaks whenever it is modified. [1] This study shows the application of the Taguchi method with logical fuzzy reasoning for multiple output optimization of high-speed CNC turning of AISI P-20 tool steel using TiN coated tungsten carbide coatings and how the cryogenic environment is the most favourable cutting parameter for high-speed CNC turning of AISI P-20 tool steel. Gupta et al. [2] analysis reveal that cutting speed and feed rate have significant effects in reducing the surface roughness, while the depth of cut has the least effect. Davim et al. [3] in this study the overall advancement issue in metal cutting operations is figured out. A study of accessible computer optimization codes, which may be used for metal cutting operations, has been given. Abuelnaga et al. [4] the orthogonal array, multi-response signal-to-noise ratio, and analysis of variance are employed to study the performance characteristics in turning operations. Karna et al. [5] in this review, the investigations were done on a CNC vertical machining focus to perform 10mm spaces on Al 6351-T6 combination workpiece by K10 carbide, four flute end milling cutter. Sreenivasulu et al. [6] this work aims to investigate the behaviour of the machining force (Fu), chip thickness ratio (CTR), and chip disposal when turning ductile (1350-O grade) and high strength (7075-T6 grade) aluminium alloys at various cutting conditions. Santos et al. [7] this work optimizes the process parameters in the turning of Aluminium Alloy 7075 using a Computer Numerical Control (CNC) machine along with response surface design. Akhtar et al. [8] this study examines the machining of Aluminium 6082 alloy utilizing a tungsten carbide slicing apparatus to distinguish the ideal boundaries for the CNC turning process. Palaniappan et al. [9] The experimental investigation on the optimization of various process parameters were used in a CNC lathe machine of SCM440 steel under dry conditions to get optimized parameter by the Taguchi technique. Arunnath et al. [10] this paper proposed the methodology of optimization technique by Taguchi L9 orthogonal array in CNC turning process in IS2062 E250 Steel done by carbide coated cutting tool. Krishnan et al. [11] this paper outline an experimental study to optimize and study the effects of process parameters in CNC turning on Surface roughness and material removal rate of SS 316 (austenite steel) work material in dry environment conditions using physical vapour deposition (PVD) coated ceramic embedded with 0.8mm nose radius and 80°negative rhombic angle.

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Prajapati et al. [12] in this paper aluminium alloy 7075 is used as a workpiece to optimize turning process parameters by applying Taguchi methods which in turn is employed to improve the quality of manufactured products, and development of designs for studying the variation which is present in all production processes. Ramreddy et al. [13] in this work EN 19 stainless steel material is used to investigate the affecting parameters while machining materials are surface roughness and MRR. Kumar M.V et al [14] in this experiment the machining parameters on CNC turning of three metals viz. 316L Stainless steel, EN24 alloy steel, and Ti 6 Al 4V alloy are studied. Saini et al. [15] in this AISI 1050 steel is used to study the effect of the main turning parameters and the experiments have been performed under dry cutting (DC), conventional wet cooling (CC), and MQL. Sarıkaya et al. [16] in this study, three different Al6063 based hybrid metal matrix composites (HMMC) samples having reinforcement with 3%, 6%, and 9% by weight respectively are fabricated using the stir casting method. Butola et al. [17] this paper outline the fractional factorial approach of D.O.E. techniques (Taguchi & Response Surface Methodology) that are applied to optimize the turning process parameter to obtain a better surface finish. Sharma et al. [18] this study analyses an assessment concerning the use of Taguchi Parameter Design for redesigning surface roughness created by a CNC machine. After probably turning model workpieces using the picked symmetrical group and boundaries, this study figured out the optimal blend of controlled boundaries for the surface roughness. Singh et al.

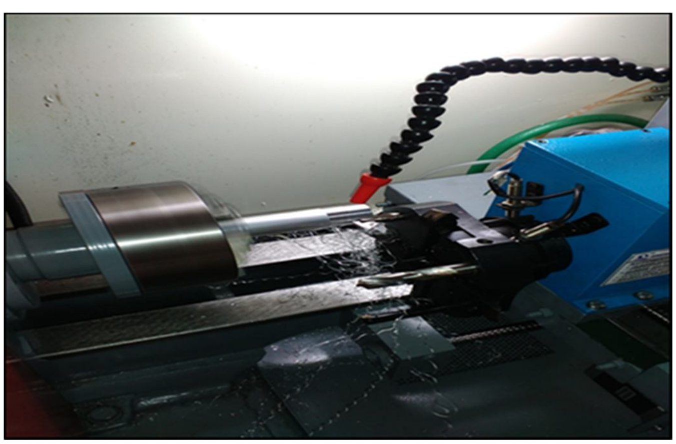
II. EXPERIMENTAL DETAILS

The CNC turner of an organization called sine wade is utilized as a machining device for both copper and aluminium metal. The organization of the two metals is unadulterated which are for the most part utilized in the modern field. The plan of tests for both the metals copper and aluminium alongside their levels are something similar. The surface roughness was estimated using a roughness-tester with a cut-off length of 0.25mm. The trials were directed on CNC turning machine, which is profoundly adaptable and fully informed regarding the most recent CNC innovation.

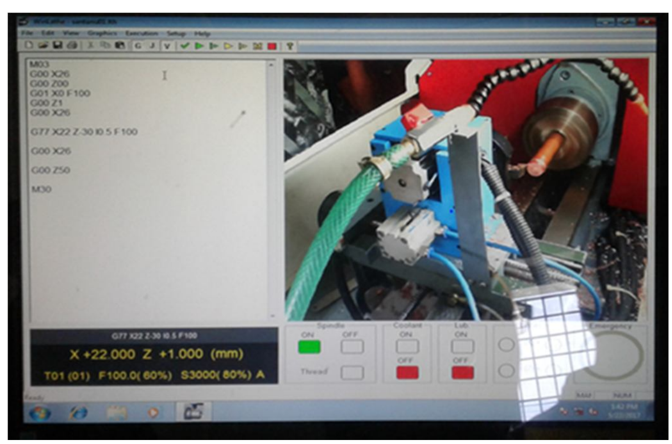
Table 1 Machined test specimen for both copper and aluminium metal.

Factors	Units	Level		
		1	2	3
Spindle Speed (S)	rpm	1200	1800*	2400
Feed Rate (F)	mm/ min	40	50*	60
Depth of Cut (D)	mm	0.3	0.4*	0.5

Surface roughness: we have estimated the surface roughness of our specimen utilizing the instrument called Mitutoyo surtronic 3+ which is convenient to quantify the surface of both the material and can be utilized in both the workshop and research facility. The Ra worth of copper is 0.923µm and aluminium is 0.732µm.



Photograph 1 CNC Machine Photograph



Photograph 2 Photographic representation of aluminium and copper bar during machining.

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III. RESULTS AND DISCUSSIONS

The point of this trial is a minimization of the surface roughness at alluring conditions. Investigation of signal to noise (S\N) ratio is determined at three unique levels however we are thinking about the accompanying rule as lower the better(LB).

$$\frac{S}{N} = -10\log\left(\frac{1}{n}\sum_{i=1}^{n} y_i^2\right)$$

Where Y is the observed data and n is the number of observations.

A. Main Effect Plot

Reaction table of means for both the metals copper and aluminium are appeared in the accompanying table. So we can without much of a stretch think about the adequacy of both the metals of individual parameters. The S/N reactions of the accompanying metals for surface roughness are taken with the assistance of Minitab programming. The ideal worth acquired at optimum design of S, F, or D reaction surface plan for both the metals are chosen by the recorded information.

Where delta is the difference between the highest and the lowest value of the parameter and rank is allotted set as descending order of the delta values.

Table 2 Response table for mean S/N ratio for copper and aluminium

	Copper			Aluminium		
Level	S	F	D	S	F	D
1	0.9449	0.9163	0.925	1.563	1.443	1.479
2	0.9458	0.9318	0.9437	1.621	1.471	1.449
3	0.9057	0.9482	0.9277	1.151	1.421	1.408
Delta	0.0401	0.0319	0.0187	0.469	0.051	0.071
Rank	1	2	3	1	3	2

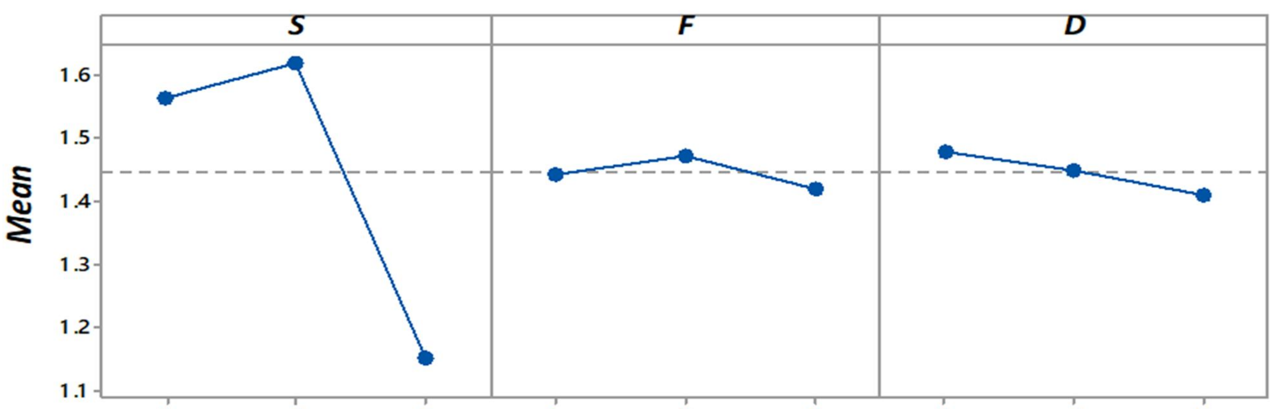


Figure 1 Main effect plot mean S/N ratio for copper

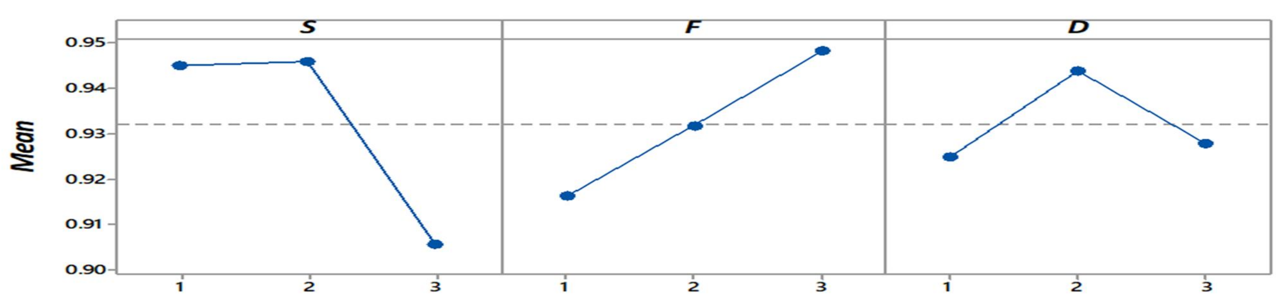
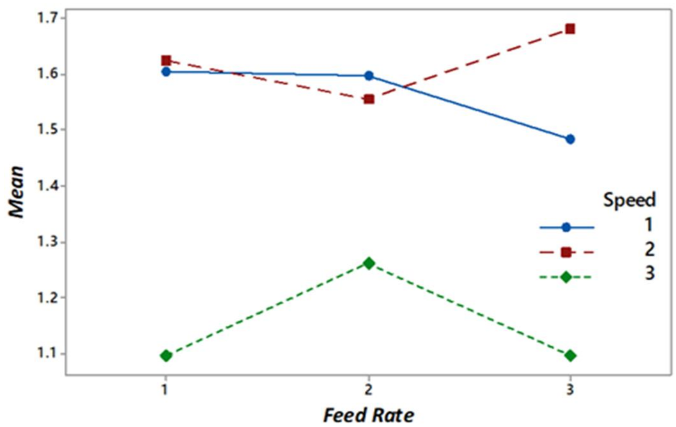


Figure 2 Main effect plot mean S/N ratio for aluminium.

B. Interaction Plots

The interaction plots for the metals aluminium and copper with similar boundaries (spindle speed, feed rate, and depth of cut) have appeared in fig. in the interaction plot of the metal copper and aluminium has better importance if the factor crosses different methods all are more fundamentally simultaneously and higher tendency (incline).



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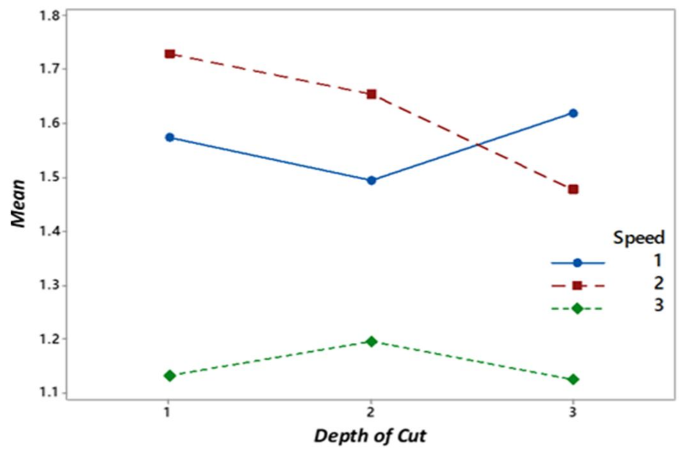

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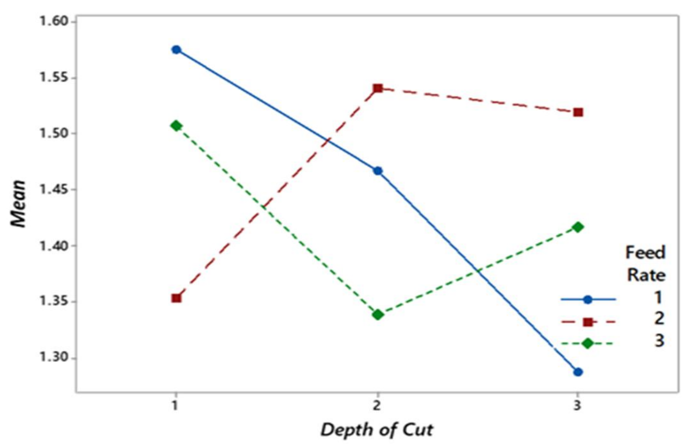
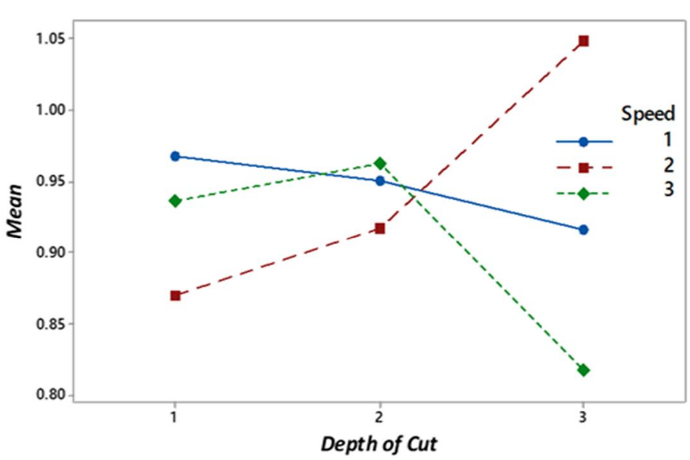


(c)

Figure 3 Interaction plots for surface roughness for copper metal (a) S vs. F, (b) S vs. D and (c) F vs. D



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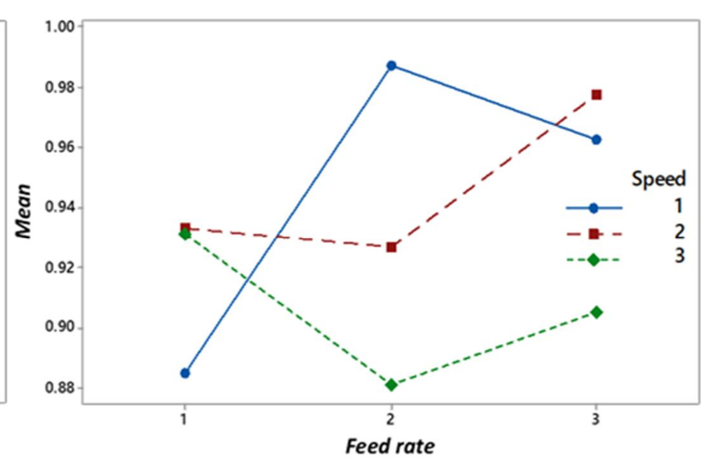

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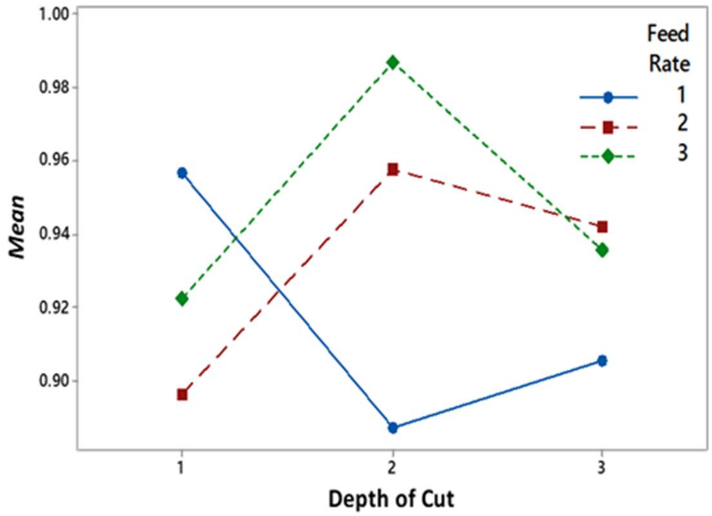


(c)

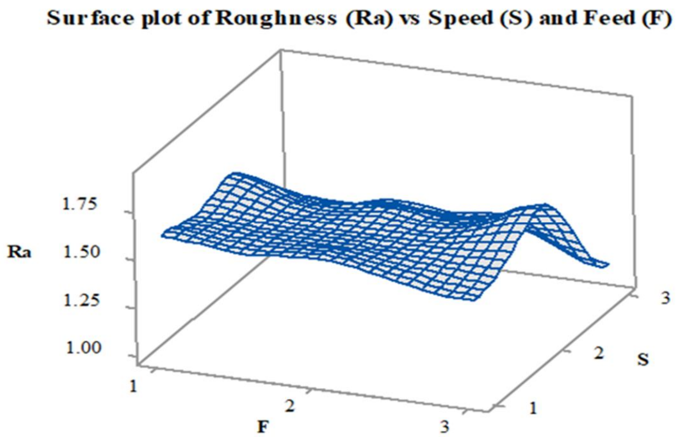
Figure 4 Interaction plots for surface roughness for aluminium metal (a) S vs. F, (b) S vs. D and (c) F vs. D.

C. Analysis of Variance (ANOVA)

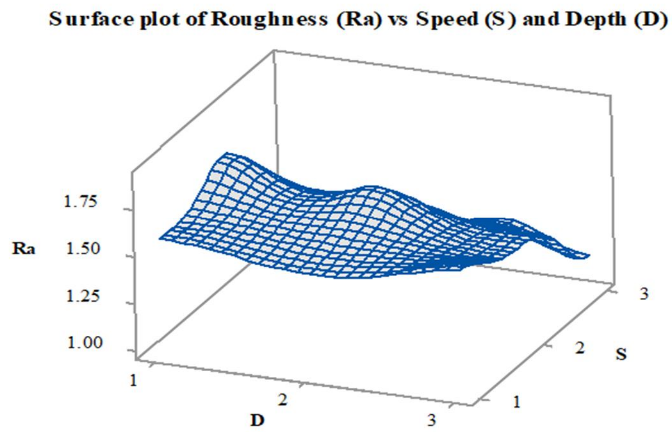
The results of analysis of variance (ANOVA) for copper and aluminium metal are calculated in the following table it is a measurable technique that is the most remarkable logical device accessible in measurements. It is utilized to discover the distinction between at least two methods, the meaning of individual boundary and their connections on the framework responses. This is finished by severing the absolute inconsistencies of the S/N proportion. This type of table represents the details of the degree of freedom, a sum of a square, mean of a square, f mean variation ratio and percentage of contribution of each interaction parameters.

Table 3 Results of ANOVA for Copper and Aluminium metal

	Copper					Aluminium				
Source	DF	SS	MS	F	P	DF	SS	MS	F	P
S	2	1.17998	0.58999	26.83	0.000	2	0.009444	0.004722	1.05	0.393
F	2	0.0116	0.0058	0.26	0.775	2	0.004578	0.002289	0.51	0.619
D	2	0.02291	0.01145	0.52	0.613	2	0.001835	0.000917	0.2	0.819
S*F	4	0.09475	0.02369	1.08	0.428	4	0.020787	0.005197	1.16	0.397
S*D	4	0.11164	0.02791	1.27	0.358	4	0.08952	0.02238	4.98	0.026
F*D	4	0.21234	0.05308	2.41	0.134	4	0.01902	0.004755	1.06	0.436
Error	8	0.17593	0.02199			8	0.035935	0.004492		
Total	26	1.80915				26	0.181119			



(a)



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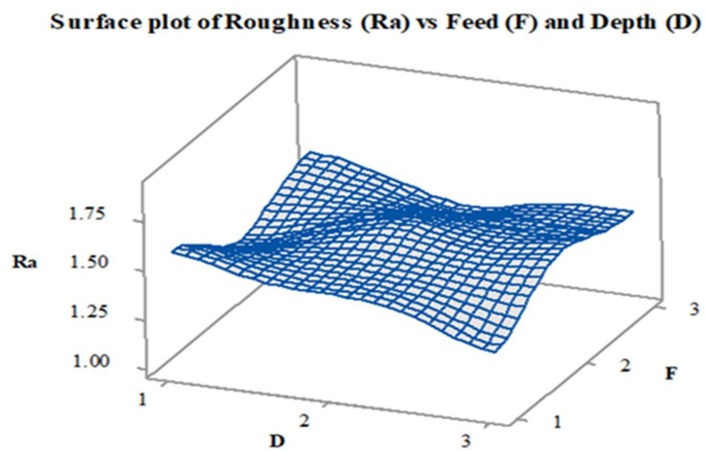
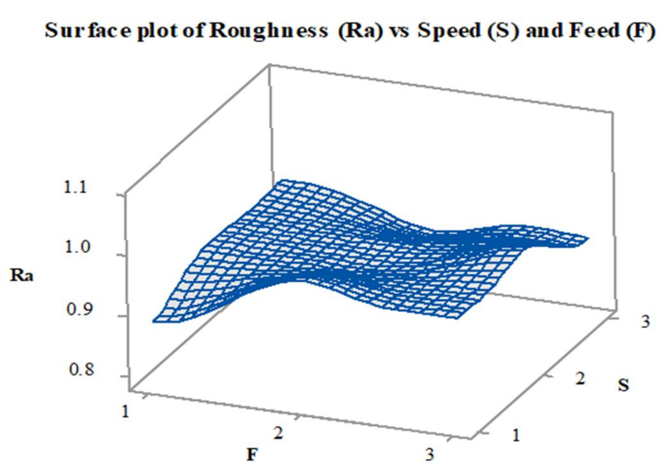


(c)

Figure 5 Surface plot of roughness of Copper metal

In figure 5 the entire surface graph for surface roughness of copper metal has a curvilinear profile following the 3D model surface plot graph, where the minimum surface roughness can be acquired when feed rate (F) and spindle speed (S) is at a moderate level, with a lower level of depth of cut (D).



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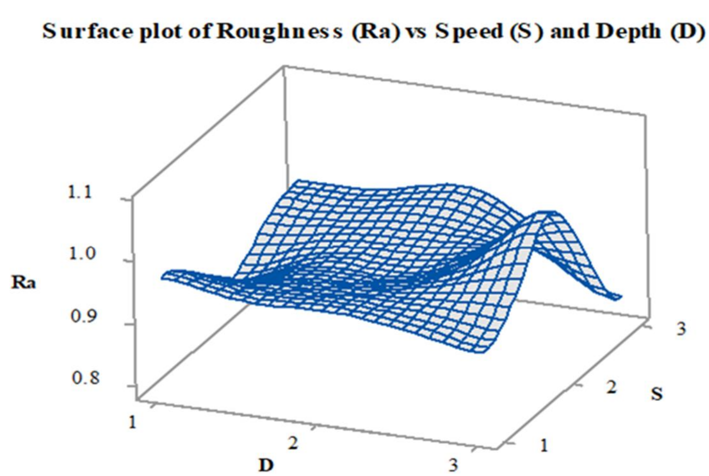

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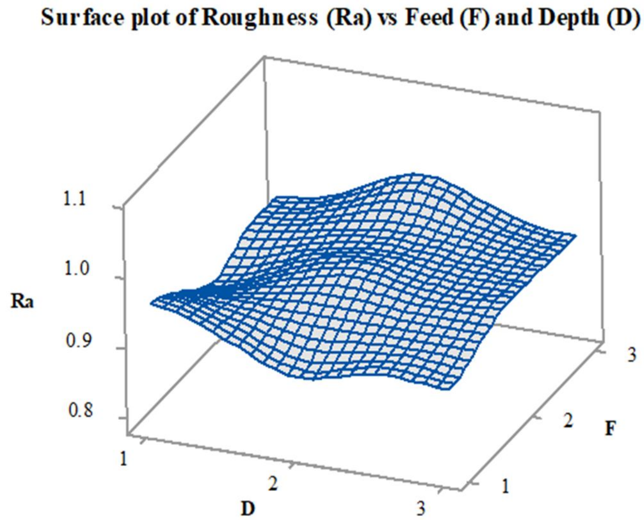

(c)

Figure 6 Surface plot of roughness of Aluminium metal

In figure 6 the entire surface graph for surface roughness of aluminium metal has a curvilinear profile by the 3D model surface plot graph, where we can round off that the surface roughness decreases when the depth of cut (D) and spindle speed (S) is at a moderate level, with a higher level of feed rate (F).

D. Confirmation Test

In the wake of acquiring the ideal boundary for both the metals copper and aluminium we need to look at and discover which metal has improved the S/N proportion got from the ideal conditions contrasted with its underlying conditions. As the optimal level of testing parameters have found, hence it is necessary that verification test can be carried out in order to evaluate the accuracy of the analysis and to validate the experimental results. The recipe for S/N proportion expectation is

$$\eta_{predicted} = \eta_m + \sum_{i=1}^{0} (\eta_i - \eta_m)$$

Where η_m is the total mean of S/N ratio, η_i is the mean S/N ratio at the optimum testing parameter level and o is the number of main design process parameters that significantly affect the characteristics of the surface roughness.

Table 4 Results of confirmation test

	Copper		Aluminium	
	Initial parameter	Optimal parameter	Initial parameter	Optimal parameter
Level	S2F2D2	S2F2D1	S2F2D2	S2F3D2
Ra (μm)	1.6818	1.4882	1.016	0.997
S/N ratio (dB)	-4.515	-3.450	-0.138	0.030
	Improvement of S/N ratio = 1.061 dB (11.51%)		Improvement of S/N ratio = 0.164 dB (1.87%)	

IV. CONCLUSION

A definitive focal point of this paper is on the utilization of the parametric design of the Taguchi technique for improving the ideal level of the turning activities for both the metals that are copper and aluminium. The general investigation of this paper causes us to notice the accompanying after effects of these metals:-

1) Taguchi's orthogonal array design strategy is used to examine the surface roughness of the metals.
2) Three design parameters (spindle speed, feed rate and depth of cut) decide the turning activity of the copper and aluminium rod among which the depth of cut is the principle boundary that influences the yield after effect of the analysis.
3) The following cutting parameters to procure the optimum levels are S2F2D1 for Copper and S2F3D2 for Aluminium. It indicates that least surface roughness can be gotten at medium range of spindle speed as well as feed rate and lower level of depth of cut for copper but for aluminium it is found at medium range of spindle speed and depth of cut but higher level of feed rate.

In spite of the fact that it could be differ at higher reaches or with other additional boundaries whenever remembered for such tasks. This paper likewise shows that among the two metals copper and aluminium which have least surface roughness in optimum levels. What's more, copper showed the better outcomes when contrasted with aluminium.

This paper gives a viable clarification on the best way to utilize Taguchi configuration to improve the interaction productivity and limit the expense and season of the assembling businesses alongside unrivalled quality items.

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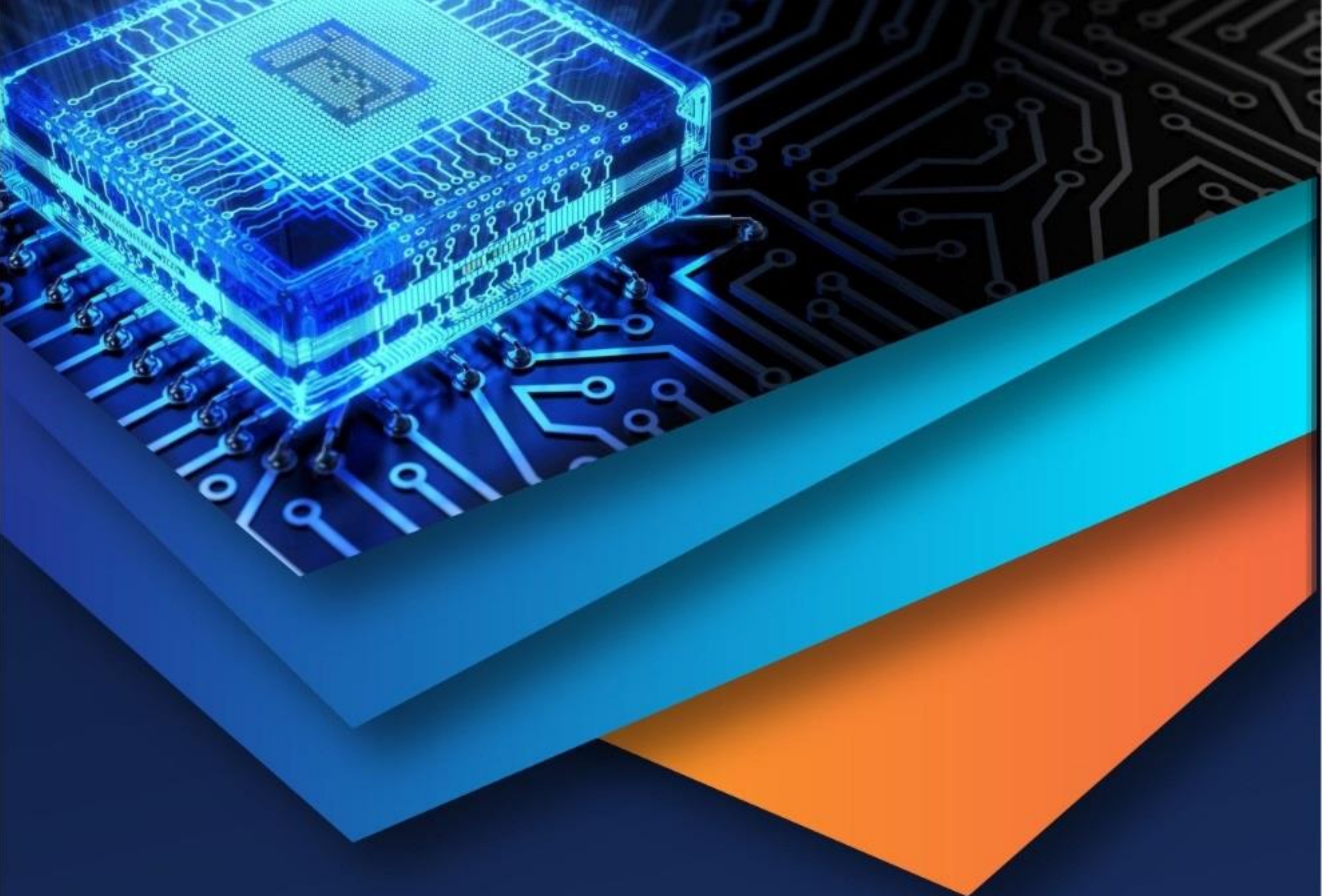

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