Statistical Approach for Behaviour of Cutting Parameters of Turning Operation

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***Abstract*— To produce any desired product, machining is one of the most important tasks. Through manipulating its system parameters, the difficulty of obtaining desired product can be accomplished. It can provide an effective method for determining optimal measuring parameters. The present examination applied Response Surface Methodology through a test study in straight turning of free cutting metal bar. The examination planned for assessing the best procedure condition which could at the same time fulfill prerequisites of both quality and just as profitability. At long last, the Optimization should be possible by many upgrading methods which pursues ANOVA to think about variety of advanced parameters. The information parameters considered in this work are cutting rate, feed, depth of cut and work material.**

Keywords*— *ANOVA, Cutting Parameters, Free Cutting Brass, Machining, optimisation, surface roughness, Turning.

I. INTRODUCTION

Machining has been a tested by the new age of materials which are regularly hard to machine. Careful comprehension of slicing mechanics can grow new techniques, devices and machining forms. Copper composite with beryllium has wide range applications because of its adaptable properties keeping pace with steels, with the extra properties of non-starting conductivity, under electric and attractive field impact and stylish look [1]. Turning is the expulsion of metal from the external distance across of a pivoting round and hollow work piece. Turning is utilized to diminish the distance across of the work piece, for the most part to a predefined measurement, and to deliver a smooth completion on the metal. Regularly the work piece will be turned with the goal that contiguous segments have various distances across [2].

Surface hardness has gotten genuine consideration for a long time. It has planned a significant structure highlight by and large, for example, parts subject to weariness loads, accuracy fits, latch gaps and necessities. Notwithstanding resilience's, surface unpleasantness forces one of the principle basic requirements for the determination of machines and cutting parameters in procedure arranging. Surface completion is the strategy for estimating the nature of an item and significant parameter in machining process. It is one of the prime prerequisites of clients for machine parts [3].

Response Surface Methodology (RSM) is an accumulation of measurable and scientific strategies valuable for creating, improving, and enhancing forms. It likewise has significant applications in the plan, advancement, and definition of new items, just as in the improvement of existing item structures.

II. LITERATURE REVIEW

K Devaki Devi.et.al [1] The present study investigates the effect of cutting parameters- cutting speed, feed rate, depth of cut, and heat treatment of work material (Be cu alloy) in turning process using uncoated CBN cutting tool. Four outputs of the machining, along which heat treatment is categoric, studied. The outputs are cutting force and cutting tool temperature. Neural Network based Genetic Algorithm approach is used to study the performance characteristics and to find out the optimal cutting parameters of the turning process for heat treated Be-cu alloy. Experimental results prove the effectiveness of this approach. In this study, the main cutting parameters that affect the cutting performance in turning operations and the best combination are determined.

K Devaki Devi et.al [2] The present paper invites optimization problem which seeks identification of the best process condition or parametric combination for the said manufacturing process. The study aimed at evaluating the best process environment which could simultaneously satisfy requirements of both quality and as well as productivity. Finally, the effect of four input variables namely cutting speed, feed, depth of cut and type of coolant on different output parameters is studied in the study.

K. Naga Lakshmi et.al [3] This research paper is focused on the analysis of optimum cutting conditions to get lowest surface roughness in turning by regression analysis. An experimental study was carried out to investigate the effect of cutting parameters like spindle speed, feed and depth of cut on surface finish in turning on Aluminum 7075 alloy. A multiple regression analysis (Ra) using analysis of variance is conducted to determine the performance of experimental measurements and to it show the effect of cutting parameters on the surface roughness. Multiple regression modeling was performed to predict the surface roughness by using machining parameters. Machining was done by using tungsten carbide tool. The objective was to establish correlation between cutting speed, feed rate and depth of cut and optimum the turning conditions based on surface roughness. These correlations are obtained by multiple regression analysis (RA).

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III. MATERIAL AND METHODOLOGY

The free cutting metal with the assignment CuZn39Pb3 has built up Itself as an astounding material for assembling a wide range of structure turned parts. The amazing machining properties of these copper-zinc amalgams is so outstanding that they are regularly utilized as benchmarks for portraying the machining properties of copper and copper composites. Composition of free cutting brass as shown in table 1 below.

TABLE I. CHEMICAL COMPOSTION OF FREE CUTTING BRASS

Element	Pb	Cu	Fe	Zn
Weight%	2.5-3.5	56.5-58.5	0.3	Rem

Typical Physical Properties:

TABLE II. PHYSICAL PROPERTIES OF FREE CUTTING BRASS

Melting Point	890°C
Density	8.4 g/cm³
Specific Heat	380 J/Kg°K
Thermal conductivity (RT)	121 W/m°K
Thermal expansion coefficient (20-200°C)	20.9 x 10-6
Electrical conductivity	28% IACS
Electrical Resistivity	0.062-ohm mm2/m

Optimal Design in CCD:

The design plan with high and low limits as indicated is utilized looking into practical considerations of the Turning operation as in the Table:

TABLE III. CONSIDERATIONS OF DESIGN PLAN

Input Factors and Levels values in coded form	**Spindle Speed (S) (RPM)**	**Feed (f) (mm/rev)**	**Depth of cut (d) (mm)**
-1	200	0.105	0.1
+1	1200	0.232	0.3

Experimental Design:

- The experimental details with the output values in the predefined central composite design matrix is given in the table. The procedural steps followed for experimentation are:
- Cutting free cutting brass bars by power saw and performing initial turning operation in Lathe to get desired dimension of the work pieces.
- Calculating weight of each specimen by the high precision digital balance meter before machining.
- Performing straight turning operation on specimen in various cutting environments involving various combinations of process control parameters: spindle speed, feed, depth of cut.
- Calculating weight of each machined plate again by the digital balance meter. And measuring surface roughness and surface profile with the help of a portable stylus-type profile meter.

TABLE IV. EXPERIMENTAL DETAILS WITH OUTPUT FACTORS.

	F1	**F2**	**F 3**	**R1**	**R2**	**R3**
Run	***Speed (RPM)***	***Feed (Mm/REV)***	***DOC (Mm)***	***S. Rough (µm)***	***MRR (Mm3/sec)***	***Force (N)***
1	910	0.184	0.2	3.4	14007	6.2
2	700	0.105	0.3	2.5	33903	8
3	550	0.105	0.1	1.7	17770	6.45
4	550	0.323	0.1	3.7	3988	8.5
5	550	0.323	0.2	6.8	24546	9.271
6	1200	0.105	0.2	2.3	17173	8.5
7	910	0.184	0.2	4.4	13753	6.5
8	1200	0.323	0.1	8	2770	7
9	1200	0.323	0.3	7.6	10471	9.205
10	550	0.184	0.2	3.9	16796	9
11	1200	0.105	0.1	2.6	5734	5.2
12	910	0.323	0.2	4.6	5995	6.37
13	910	0.184	0.2	4.4	17366	6.24
14	550	0.184	0.2	4.04	26930	9
15	910	0.184	0.1	5.2	9880	3.837
16	910	0.323	0.1	6.1	1339	4.88
17	700	0.105	0.3	3.25	36391	8
18	1200	0.184	0.3	3.95	14608	10
19	550	0.323	0.3	6.55	14313	9
20	910	0.184	0.1	3.85	2485	4

Analysis of Surface roughness(R):

Table depicts the significance of the model and its terms through ANOVA.

TABLE V. ANALYSIS OF VARIANCE TABLE FOR SURFACE ROUGHNESS

Source	**Sum of Squares**	**df**	**Mean Square**	**F-value**	**P-value**	
Model	49.90	6	8.32	11.42	0.0002	Significant
A-s	1.65	1	1.65	2.26	0.01564	
B-f	46.16	1	46.16	63.41	< 0.0001	
C-d	0.7292	1	0.729	1.00	0.03352	
AB	2.81	1	2.81	3.86	0.0712	
AC	3.61	1	3.61	4.96	0.0442	
BC	0.6947	1	0.694	0.9543	0.3464	
Residual	9.46	13	0.728			
Lack of Fit	7.59	8	0.949	2.54	0.1597	not Significant
Pure Error	1.87	5	0.373			
Cor Total	59.36	19				

From the Table, the Model F, the Model F-value of 11.42 implies the model is significant. Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case A, B, C are significant model terms. Values greater than 0.1000 indicate the model terms are not significant.

The Predicted R^2 of 0.6455 is in reasonable agreement with the Adjusted R^2 of 0.7670; i.e. the difference is less than 0.2. Adeq Precision measures the signal to noise ratio. A ratio greater than 4 is desirable. The ratio of 10.905 indicates an adequate signal. This model can be used to navigate the design space.

An interaction occurs when the response is different depending on the settings of two factors. Plots make it easy to interpret two factor interactions. They will appear with two non-parallel lines, indicating that the effect of one factor depends on the level of the other. The Interaction graph in figure shows that speed is effects Roughness (R) much more than feed and depth of cut. In the figure, the actual values are marked as dots i.e., experimental values, then the straight line of predicted values are drawn using prediction equations.'

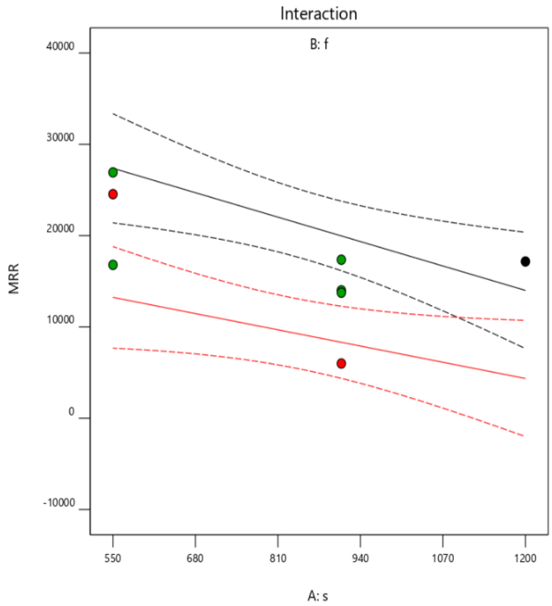

Fig.1. Interaction plot of SR

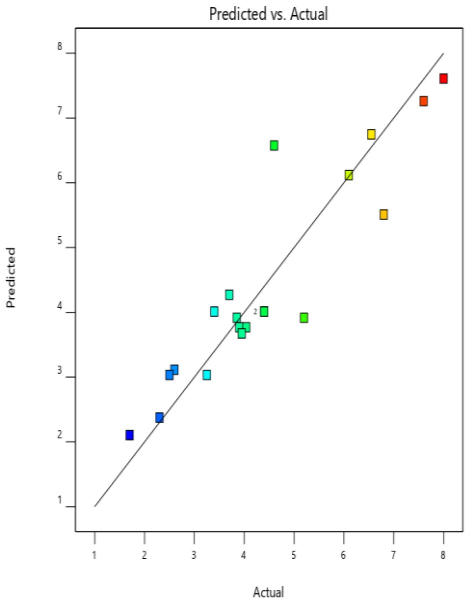

Fig.2. Residual plot of SR

Analysis of metal removal rate (MRR):

Table depicts the significance of the model and its terms through ANOVA.

TABLE VI. ANALYSIS OF VARIANCE TABLE FOR MATERIAL REMOVE RATE

Source	**Sum of Squares**	**df**	**Mean Square**	**F-value**	**p-value**	
Model	1.59E+09	6	2.65E+08	11.50	0.0001	Significant
A-s	3.52E+08	1	3.52E+08	15.24	0.0018	
B-f	4.30E+08	1	4.30E+08	18.61	0.0008	
C-d	6.35E+08	1	6.35E+08	27.47	0.0002	
AB	1.04E+07	1	1.04E+07	0.451	0.5132	
AC	9.22E+06	1	9.22E+06	0.399	0.5386	
BC	4.65E+07	1	4.65E+07	2.01	0.1797	
Residual	3.00E+08	13	2.31E+07			
Lack of Fit	2.10E+08	8	2.63E+07	1.46	0.3506	Not significant
Pure Error	8.99E+07	5	1.79E+07			
CorTotal	1.89E+09	19				

From the Table, it is clear that the Model F-value of 11.50 implies the model is significant. Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case A, B, C are significant model terms.

The Predicted R^2 of 0.5210 is not as close to the Adjusted R^2 of 0.7683 as one might normally expect; i.e. the difference is more than 0.2. This may indicate a large block effect or a possible problem with your model and/or data. Things to consider are model reduction, response transformation, outliers, etc.

All empirical models should be tested by doing confirmation runs. Adeq Precision measures the signal to noise ratio. A ratio greater than 4 is desirable. Your ratio of 12.012 indicates an adequate signal. This model can be used to navigate the design space.

The Interaction graph in figure shows that speed is effects MRR much more than feed and depth of cut. In the figure, the actual values are marked as dots i.e., experimental values, then the straight line of predicted values are drawn using prediction equations.

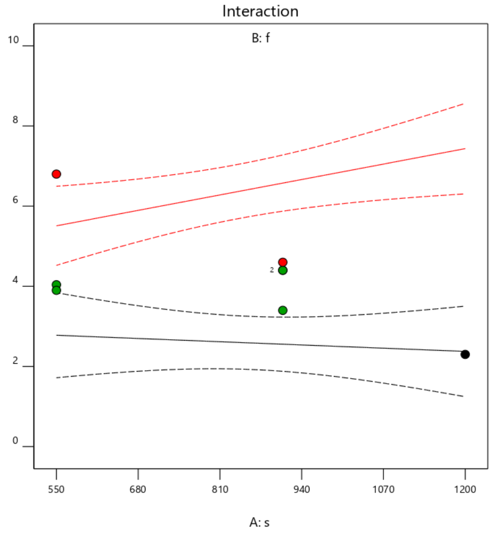

Fig.3. Interaction plot of MRR

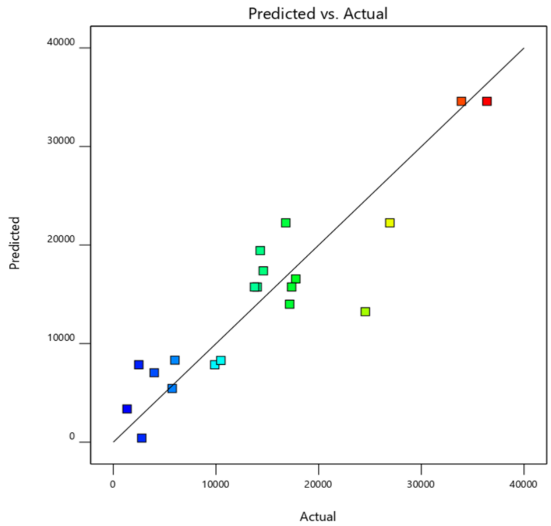

Fig.4. Residual plot of MRR

Analysis of Cutting Force (F):

Table depicts the significance of the model and its terms through ANOVA.

From the Table, it is clear that the Model F-value of 548.99 implies the model is significant. Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case A, B, C are significant model terms.

The Predicted R^2 of 0.9884 is in reasonable agreement with the Adjusted R^2 of 0.9962; i.e. the difference is less than 0.2. Adeq Precision measures the signal to noise ratio. A ratio greater than 4 is desirable. Your ratio of 75.312 indicates an adequate signal. This model can be used to navigate the design space.

The Interaction graph in figure shows that feed effects F much more than speed and depth of cut. In the figure, the actual values are marked as dots i.e., experimental values, then the straight line of predicted values are drawn using prediction equations.

TABLE VII. ANALYSIS OF VARIANCE TABLE FOR CUTTING FORCE

Source	**Sum of Square**	**df**	**Mean Square**	**F-value**	**p-value**	
Model	64.97	9	7.22	548.99	< 0.0001	significant
A-s	0.5245	1	0.524	39.89	< 0.0001	
B-f	0.5268	1	0.526	40.07	< 0.0001	
C-d	22.17	1	22.17	1686.06	< 0.0001	
AB	0.0547	1	0.054	4.16	0.0687	
AC	1.31	1	1.31	99.79	< 0.0001	
BC	3.96	1	3.96	301.33	< 0.0001	
A^2	21.86	1	21.86	1662.61	< 0.0001	
B^2	0.0335	1	0.033	2.55	0.1417	
C^2	1.66	1	1.66	126.35	< 0.0001	
Residual	0.1315	10	0.013			
Lack of Fit	0.0651	5	0.013	0.9817	0.5078	not significant
Pure Error	0.0664	5	0.013			
Cor Total	65.10	19				

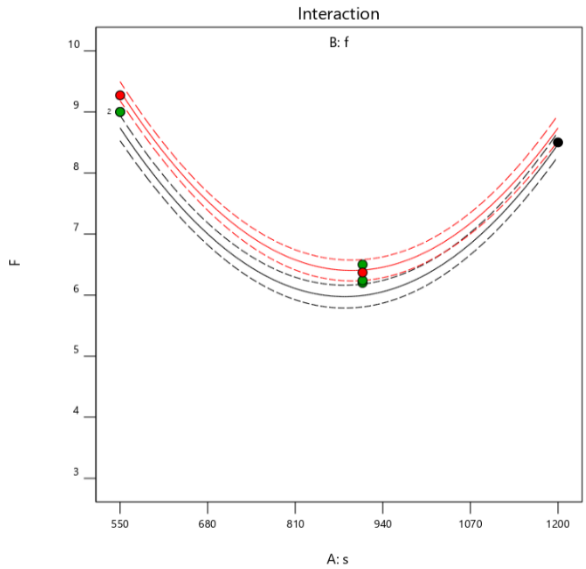

Fig.5. Interaction plot of Cutting Force

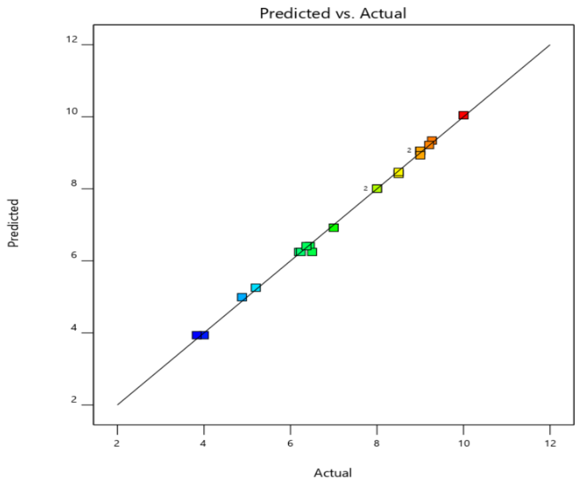

Fig.6. Residual plot of Cutting Force

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IV. RESULTS

TABLE VIII. OPTIMAL SOLUTION

S	F	D	Ra	MRR	Cutting force
790.48	0.105	0.166	2.579	19055	5.4401

Surface plots for optimal outputs

The three-dimensional surface plots given below depict the behaviour of response surfaces with respect to the most influencing input parameters at optimal setting.

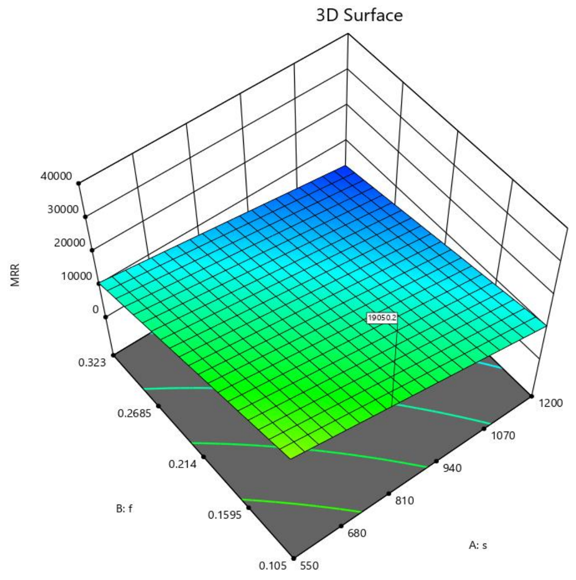

Fig.7. Surface plot for SR

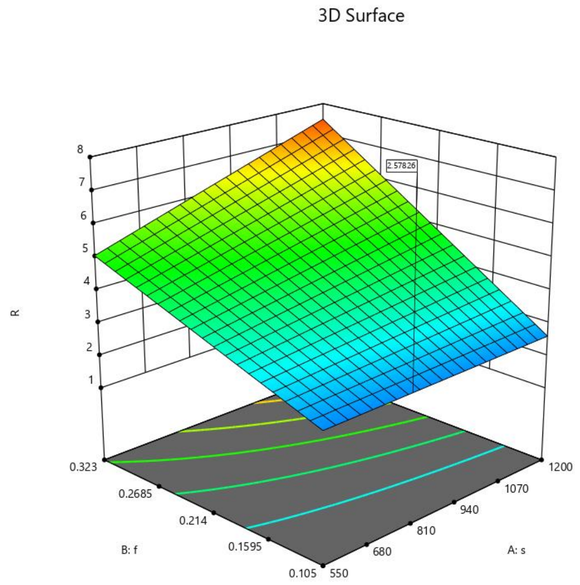

Fig.8 Surface plot for MRR

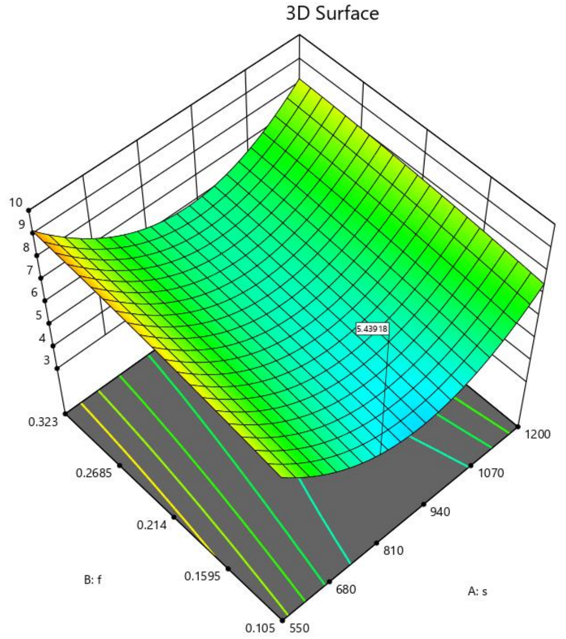

Fig.9. Surface plot for Cutting Force

CONCLUSION

From the observation the following results are summarized.

1. Feed has more significance while speed and depth of cut have less significant effect on surface roughness (Ra).
2. Speed has more significant effect while feed and depth of cut have less significant effect on MRR.
3. Feed has more significant effect while speed and depth of cut have less significant effect on Cutting force(F).

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