



## Investigation of Effecting Parameters in a Turning Operation

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### Abstract

In this study multi objective optimization is utilized to optimize a turning operation to reveal the appropriate level of process features. The goal of this work is to evaluate the optimal combination of cutting parameters like feed, spindle speed, inclination angle and workpiece material to have a best surface quality Taguchi technique L9 mixed orthogonal array, has been adopted to optimize the roughness of surface. Three rods of length around (200 mm) for the three metals are used for this work. Each rod is divided into three parts with 50 mm length. For brass the optimum parametric mix for minimum Ra is A1, B1 and C3, i.e., at tool inclination angle (5), feedrate of 0.01, spindle speed of 1200 rpm. For copper the optimal parameters combination for best Ra is A1, B1 and C3, i.e., at tool inclination angle (5), feedrate of 0.01, spindle speed of 1200 rpm. For bronze the optimum parameters mix for minimum Ra is A1, B1 and C3, i.e., at tool inclination angle (5), feedrate of 0.01, spindle speed of 1200 rpm.

**Keywords:** Taguchi technique, spindle speed, feed rate, inclination angle.

### 1. Introduction

Recently, modern machining techniques face many difficulties to gain the best quality in terms of dimensional accuracy of the work piece, surface quality, low wear on cutting tools and less machining cost. Surface finish of the machined part is one of the common significant criteria to evaluate the operation quality. The literature review has discovered that many attempts have been done to estimate the optimal cutting conditions in the operation of turning [1]. It is very critical part to evaluate and implement optimal machining parameters combination along with the use of suitable cutting tools. Surface finish become the most important technical requirement and it is an index of product quality. The best surface quality is required for perfection of the features, strength of fatigue, resistance of corrosion and aesthetic appeal of the product [2]. The difference in the material properties and added elements is found in the material of work

piece besides many factors influencing surface quality. Suitable selection of cutting condition and tool can give better tool life and good surface finish. Hence, a good distribution of experiments by Taguchi technique for cutting conditions is employed to find their effect on surface roughness [3]. The turning is the technique of removing the access material from the outer surface of a cylindrical shaft or circular workpiece. Furthermore it is used to minimize the dimensions of the work piece, often to a required dimension, and to produce a fine surface on the material. Usually the work piece will be machined so that adjacent parts have many diameters. Turning is the machining technique that gives cylindrical parts. It can be defined as the production of an external or internal surface:

- for the rotating work piece.
- for a single-point tool.

- for the feeding of tool parallel to the axis of the machined part and to remove the outer surface of the work [4].

K.Mani Lavanya, et al. examined the role of factors affecting the quality of surfaces machined by turning operation for the AISI-1016 steel. Experiments design was set for the analysis of the effect of the turning conditions like feed rate, cutting speed and cutting depth on the surface finish. The outputs of the turning tests were used to specify the main parameters influencing surface finish by the Analysis of variance technique. The most affecting parameter influencing the surface finish in the turning process was the feed rate [1]. Ranganath M S, et al. studied the factors influencing the quality of surfaces machined by the turning for Aluminium 6061. The process conditions taken are feed, speed and cutting depth. Experiments design was conducted for the analysis of the effect of the process conditions on the surface quality by adopting Taguchi technique. The outputs of the experiments were used to reveal the main elements influencing surface quality by the Analysis of Variance technique. The most influential process conditions on surface quality were speed and feed [3]. Deepak D, Rajendra B, aimed to optimize the process variables such as cutting depth, cutting velocity and feed rate on surface quality machined for the parts. Analysis is performed utilizing Taguchi design technique. From the results, the most significant process parameters was the feed rate which influence the surface quality, then cutting velocity and cutting depth. Increasing feed rate and cutting depth will increasing the surface defects [5]. Pankaj Kumar Sahu, et al, studied the relation between differences in hardness produced in the machined surface by turning operation depending on different machining conditions like feed, spindle speed and cutting depth have been studied. Taguchi technique has been adopted to plan the experiment where the material used is aluminum. The main effects have been calculated and percentage contribution of various process parameters influencing hardness also revealed [6]. Dharindom Sonowal, et al. In this research the role of many cutting conditions viz. depth of cut, Spindle speed and Feed on surface finish of AISI 1020 mild steel bar in turning was studied and analyzed to reveal best surface quality. All the experiments are conducted on HMT LB25 lathe machine using M2 HSS cutting tool. Wide ranges of condition of interest have been adopted through some preliminary experiments (One Factor at a Time experiments). At last a combined experiment has been carried out using Taguchi's

L27 orthogonal array to reveal the main influence and combination effect of all process outputs [7]. In this work three metals have been chosen as workpiece to make a comparison between them in term of surface roughness.

## 2. Taguchi Method

Taguchi's parametric technique is the effective technique for robust design which gives a simple and systematic qualitative optimum design to a relatively low cost. Taguchi technique of off-line quality control includes all steps of product/process development. Therefore, the best way for evaluating high quality at low cost is Design of Experiments (DOE). In this research Taguchi's technique is used to show the role of process conditions like, spindle speed, feed, tool inclination angle and workpiece material on surface quality of work material on the other hand, turning with cutting tools and getting an optimum combination of conditions may result in best surface quality [3].

## 3. Experimental Work

In this work three metals have been chosen as the specimen, zinc, copper and brass. Three rods of length around (200 mm) for the three metals has been taken for this work. Each rod was dividing into three parts with 50 mm length as shown below in Fig. 1. The dimensions used is ( $\varnothing = 30$  mm) for the specimen of the high speed steel cutting tool. In this work nine experiments are performed for each work piece utilizing turning operation for three variables. Surface finishing is measured by using (MarSurf PS1) device for 27 experiments for the three workpieces. The parameters and their levels are listed in the Table 1. The distribution of the experiments and the machining parameters are shown in the Table 2.

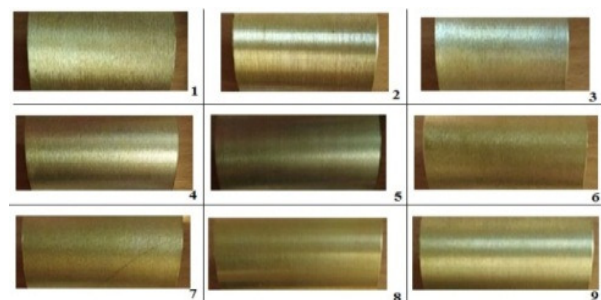


Fig. 1. The work pieces after machining.

**Table 1,**  
**Machining variables and their levels**

Code	Cutting parameter	Levels		
		1	2	3
A	Tool inclination angle (degree)	5	0	-5
B	Feedrate (mm/ min)	0.01	0.04	0.08
C	Spindle speed (rpm)	540	800	1200

**Table 2,**  
**The distribution of the experiments and the parameters.**

Ex. No.	Coded values			Real values		
	A	B	C	Angle (degree)	Feedrate (mm/ min)	Spindle (rpm)
1	1	1	1	5	0.01	540
2	1	2	2	5	0.04	800
3	1	3	3	5	0.08	1200
4	2	1	2	0	0.01	800
5	2	2	3	0	0.04	1200
6	2	3	1	0	0.08	540
7	3	1	3	-5	0.01	1200
8	3	2	1	-5	0.04	540
9	3	3	2	-5	0.08	800

## 4. Results and Discussion

Table 3 explains the experimental readings of machining brass alloy depending on L9 orthogonal array. The surface roughness (Ra) in  $\mu\text{m}$  has been measured. The mean of these features and signal to noise (S/N) ratio (in decibels) are shown for the output of the process in the Tables 4 and 5. Also Figs. 2 and 3 show the affected plot of the factors versus means and S/N ratio.

### 4.1. Estimation of Optimum Parameters for Roughness (Ra) for Brass

Figs. 2 and 3 illustrate the plot of machining variables versus the response (Surface roughness) for mean and S/N ratio. As explained in Table 3 of the results of means, all the three used conditions of tool inclination angle (A), feedrate (B) and spindle speed (C) practically affect the

mean of the (Ra) values. It can be noticed that the optimum parametric mix for minimum Ra is A1, B1 and C3, i.e., at tool inclination angle (5), feedrate of 0.01, spindle speed of 1200 rpm. It is found that the parameters combination within the proposed range as detailed previously produced lowest surface roughness of brass alloy. Using these data the optimum surface roughness can be predicted according to the relation:

$$\text{Predicted Mean (Ra)} = A1+B1+C3-2*(\text{average mean}) [1]$$

Where:

A1= Average of (Ra) at the first level of tool inclination angle.

B1= Average of (Ra) at the first level of feedrate

C3= Average of (Ra) at the third level of spindle speed.

From Table 4 the predicted mean (Ra) equal to =  $2.525+3.873+3.567-2*4.191 = 1.583 \mu\text{m}$

Table 3,  
Results for brass.

Exp. No.	Coded Values			Real Values			Measurements				
	A	B	C	Angle (degree)	Feedrate (mm/min)	Spindle (rpm)	Ra1	Ra2	Ra3	Means	S/N
1	1	1	1	5	0.01	540	2.533	2.584	2.539	2.552	-8.138
2	1	2	2	5	0.04	800	2.430	2.210	2.480	2.373	-7.518
3	1	3	3	5	0.08	1200	2.650	2.680	2.620	2.650	-8.465
4	2	1	2	0	0.01	800	4.754	4.853	4.844	4.817	-13.655
5	2	2	3	0	0.04	1200	3.700	3.900	3.800	3.800	-11.597
6	2	3	1	0	0.08	540	4.950	4.910	4.980	4.946	-13.886
7	3	1	3	-5	0.01	1200	4.220	4.280	4.250	4.250	-12.567
8	3	2	1	-5	0.04	540	5.422	5.437	5.485	5.448	-14.724
9	3	3	2	-5	0.08	800	6.870	6.900	6.880	6.883	-16.756

Table 4,  
Response table for means for brass.

Level	Angle (degree)	Feed (mm/ min)	Spindle (rpm)
1	2.525	3.873	4.316
2	4.521	3.874	4.691
3	5.527	4.827	3.567
Delta	3.002	0.954	1.125
Rank	1	3	2

Table 5,  
Response table for signal to noise ratios for brass.

Level	Angle (degree)	Feed (mm/min)	Spindle (rpm)
1	-8.040	-11.454	-12.250
2	-13.047	-11.280	-12.643
3	-14.683	-13.036	-10.877
Delta	6.643	1.756	1.766
Rank	1	3	2

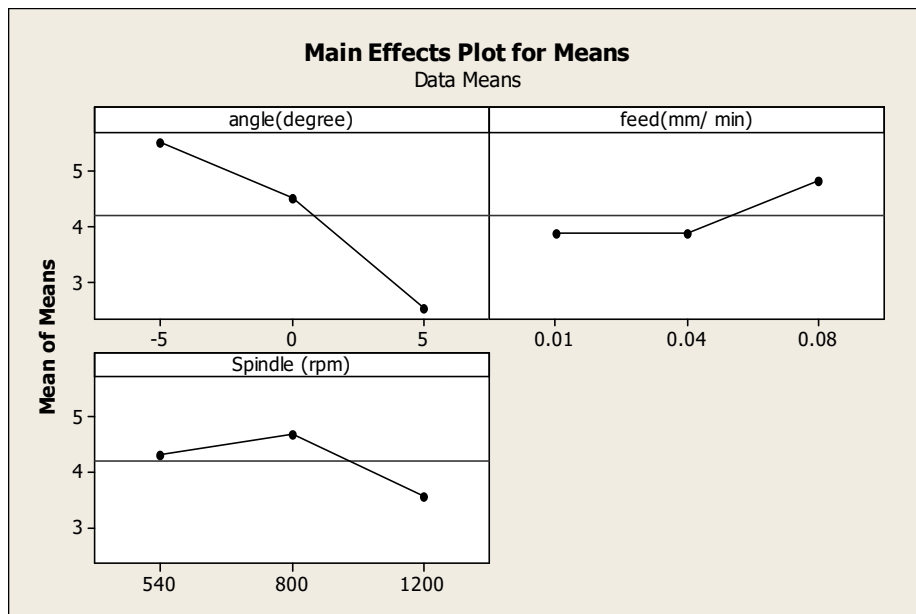


Fig. 2. Plot for means for brass.

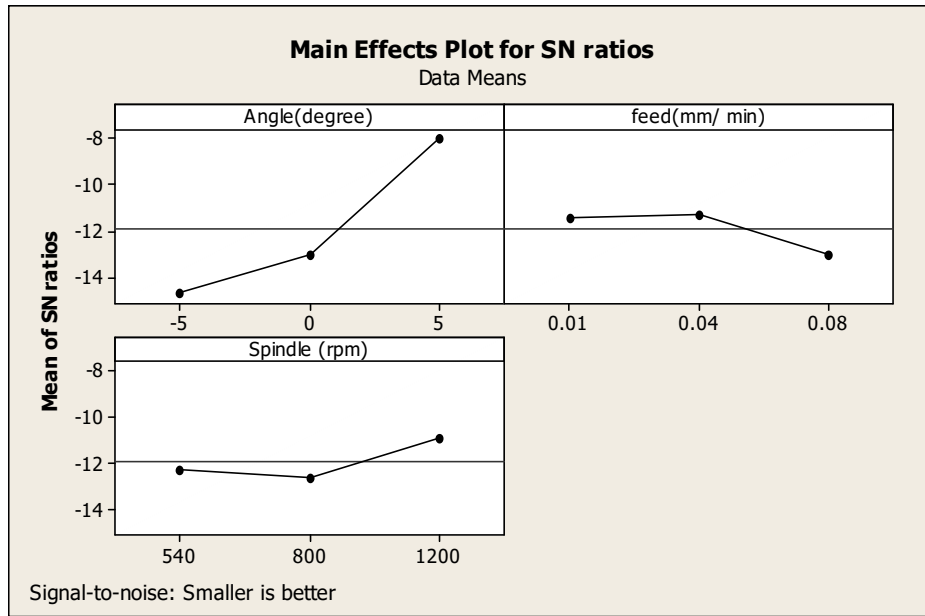


Fig. 3. Plot for signal to noise for brass.

Table 6 represents the experimental results of machining copper alloy depending on Taguchi L9 mixed array. The output characteristic, Ra in  $\mu\text{m}$  has been measured and evaluated. The average (mean) of this feature and S/N ratio (in decibels) are shown for each feature in the Tables 7 and 8. Also Figs. 4 and 5 show the effect plot of the factors versus means and S/N ratio.

#### 4.2 Estimation of Optimum Parameters for Roughness (Ra) for Copper

Figs 4 and 5 show the plot of machining variables versus the response (Surface Roughness) for mean and S/N ratio. As seen in Table 7 which shows the results of means, all the machining parameters of tool inclination angle (A), feedrate (B) and spindle speed (C) significantly influence both the mean and the variation in the (Ra) values. It can be noticed that the optimal parameters

combination for best Ra is A1, B1 and C3, i.e., at tool inclination angle (5), feedrate of 0.01, spindle speed of 1200 rpm. It is proposed that the parameters combination within the specified range as mentioned above gives minimum surface defects Ra for finishing of brass alloy. Using these data the optimum surface roughness can be predicted according to the relation:

$$\text{Predicted Mean (Ra)} = A1+B1+C3-2*(\text{average mean})$$

Where:

A1= Average of (Ra) at the first level of tool inclination angle.

B1= Average of (Ra) at the first level of feedrate.

C3= Average of (Ra) at the third level of spindle speed.

$$\text{from Table 4 the predicted mean (Ra)} = 2.261+2.563+2.605 - 2*5.978 = 1.451 \mu\text{m}$$

Table 6, Results for copper.

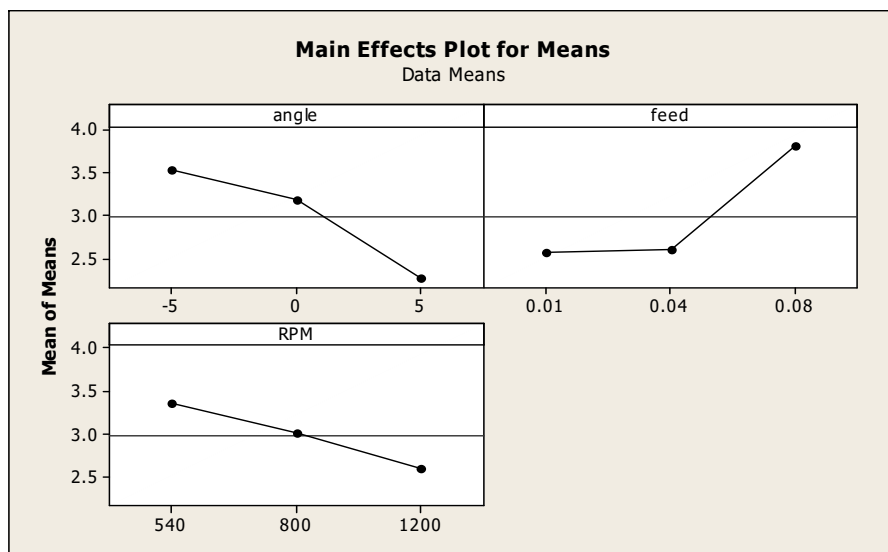
Ex. No	Coded values			Measurements				
	A	B	C	Ra1	Ra2	Ra3	Means	S/N
1	1	1	1	2.38	2.48	2.38	2.38	-7.55
2	1	2	2	1.82	1.85	1.864	1.84	-5.32
3	1	3	3	2.41	2.51	2.719	2.55	-8.14
4	2	1	2	2.69	2.59	2.634	2.64	-8.43
5	2	2	3	2.45	2.85	2.487	2.59	-8.31
6	2	3	1	4.26	4.46	4.220	4.31	-12.69
7	3	1	3	2.58	2.63	2.780	2.66	-8.51
8	3	2	1	3.34	3.35	3.412	3.36	-10.54
9	3	3	2	4.55	4.65	4.398	4.35	-13.13

**Table 7,**  
Response table for means.

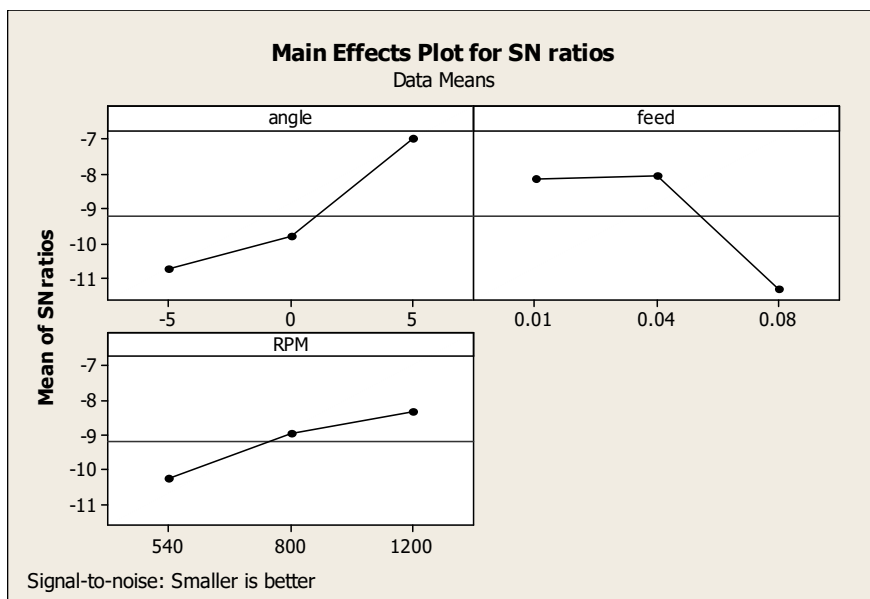
Level	Angle (degree)	Feed (mm/min)	Spindle (rpm)
1	2.261	2.563	3.355
2	3.185	2.605	3.008
3	3.522	3.800	2.605
Delta	1.262	1.237	0.750
Rank	1	2	3

**Table 8,**  
Response table for signal to noise ratios smaller is better.

Level	Angle (degree)	Feed (mm/min)	Spindle (rpm)
1	-10.732	-8.168	-10.267
2	-9.819	-8.065	-8.966
3	-7.008	-11.327	-8.327
Delta	3.724	3.263	1.939
Rank	1	2	3



**Fig. 4.** Plot for means for copper.



**Fig. 5.** Plot for signal to noise for copper.

Table 9 represents the measured results of machining copper alloy depending on Taguchi L9 mixed array. The average and S/N ratio (in decibels) are shown for each feature in the Tables 10 and 11. Also Figs. 6 and 7 show the plot of the parameters versus means and S/N ratio.

#### 4.3 Estimation of Optimum Parameters for Roughness (Ra) for Bronze

And to Figures (6) and (7) show the Plot of machining factors versus the response (Surface Roughness) for mean and S/N ratio. As seen in table (7) the results of means, all the selected input parameters of tool inclination angle (A), feedrate (B) and spindle speed (C) mainly influenced both the mean and the difference in the (Ra) values. It can be noticed that the optimum

parameters mix for minimum Ra is A1, B1 and C3, i.e., at tool inclination angle (5), feedrate of 0.01, spindle speed of 1200 rpm. It is clear that the parameters combination within the specified range as mentioned above produce best surface quality Ra for finishing of brass alloy. Using these data the optimum surface roughness can be predicted according to the relation:

Predicted Mean (Ra) = A1 + B1 + C3 - 2\*(average mean)

A1 = Average of (Ra) at the first level of tool inclination angle.

B1 = Average of (Ra) at the first level of feedrate.

C3 = Average of (Ra) at the third level of spindle speed.

From Table 4 predicted mean (Ra) =  $2.519 + 3.370 + 3.525 - 2 * 3.796 = 1.822 \mu\text{m}$

**Table 9,  
Results for bronze.**

Ex. No.	Coded values			Measurements				
	A	B	C	Ra1	Ra2	Ra3	Mean	S/N
1	1	1	1	2.35	2.45	2.37	2.39	-7.57
2	1	2	2	1.53	1.54	1.56	1.54	-3.78
3	1	3	3	3.57	3.61	3.68	3.62	-11.17
4	2	1	2	4.32	4.73	4.87	4.64	-13.34
5	2	2	3	3.76	3.88	3.98	3.87	-11.77
6	2	3	1	4.69	4.97	4.94	4.86	-13.75
7	3	1	3	3.03	3.17	3.02	3.07	-9.76
8	3	2	1	5.05	4.86	4.95	4.95	-13.90
9	3	3	2	5.25	5.18	5.12	5.18	-14.2

**Table 10,  
Response table for means for bronze.**

Level	Angle (degree)	Feed (mm/min)	Spindle (rpm)
1	2.519	3.370	4.073
2	4.464	3.460	3.792
3	4.407	4.559	3.525
Delta	1.944	1.189	0.548
Rank	1	2	3

**Table 11,  
Table for signal to noise ratios for bronze smaller is better.**

Level	Angle (degree)	Feed (mm/min)	Spindle (rpm)
1	-12.656	-10.228	-11.744
2	-12.958	-9.820	-10.477
3	-7.510	-13.076	-10.904
Delta	5.448	3.256	1.267
Rank	1	2	3

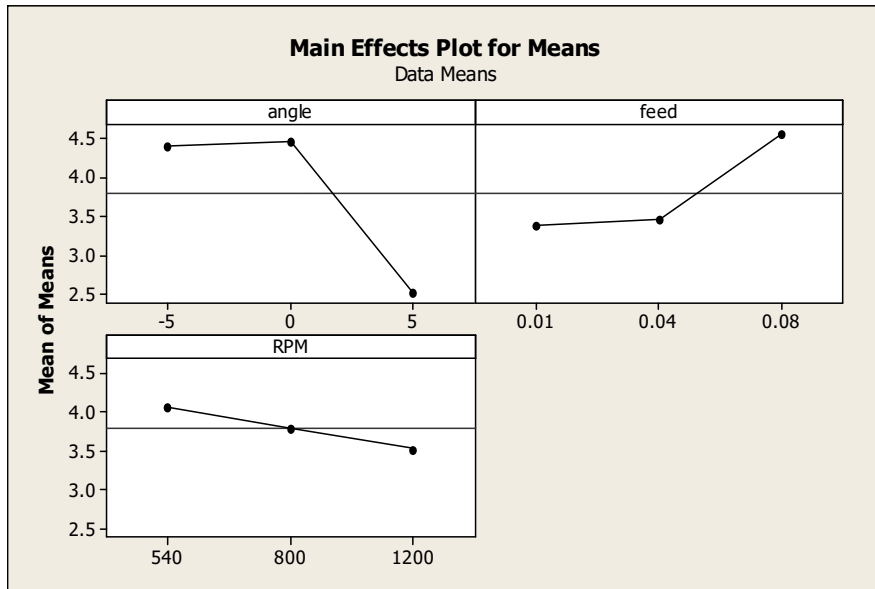


Fig. 6. Plot for means for bronze.

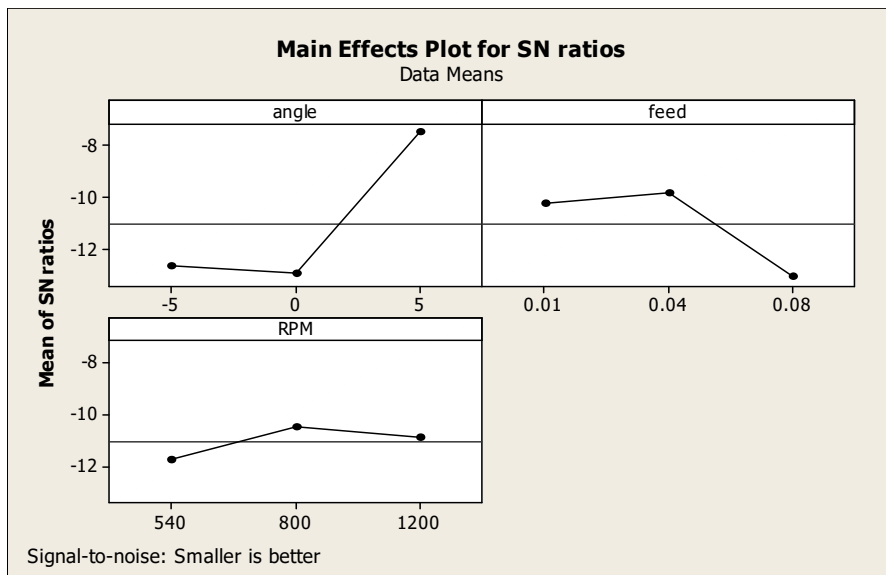


Fig. 7. Plot for signal to noise for bronze.

### 5. Conclusions

The most important results revealed from the present work are listed as in the following:

- 1- The optimal parametric combination of machining factors for minimum surface roughness (Ra) for brass, copper and bronze are A1 B1 C3, i.e., at (5) tool inclination angle, feedrate of 0.01 and spindle speed of 1200 rpm. Tool inclination angle has the highest effect then spindle speed and then feed rate on roughness (Ra) as seen from the rank of the effect of parameters.

- 2- From the calculated predicted values of the surface roughness for the three metals the minimum surface roughness is found in copper because of the ductility of the copper.
- 3- It has been found that Taguchi technique is good tool for predicting the process outputs.

### 6. References

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## دراسة العوامل المؤثرة في عملية الخراطة

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## الخلاصة

في هذه الدراسة تم تبني الامثلية متعددة الاهداف لتحقيق الامثلية لعملية الخراطة و اكتشاف الظروف الملائمة لخواص العملية. ان الهدف من هذا البحث هو ايجاد افضل مجموعة عوامل قطع مثل التغذية، سرعة الدوران، زاوية ميلان الحد القاطع و معدن المشغولة لاجاد افضل نوعية انهاء سطحي. تم تبني تقنية تاكوجي بمصفوفة L9 لاجاد افضل انهاء سطحي. ثلاثة قضبان بطول ٢٠٠ ملم لثلاثة معادن تم استخدامها في هذا البحث. كل عمود مقسم الى ثلاثة اقسام بطول ٥٠ ملم. و قد وجد ان افضل العوامل تعطي اقل خشونة سطحية بالنسبة لمعدن البراص كانت A1,B1 و C3 اي عند زاوية ميلان عدة ( ٥ ) درجة و معدل تغذية ٠,٠١ و سرعة دوران ١٢٠٠ دورة بالدقيقة. أما بالنسبة للنحاس فكانت افضل ظروف هي A1,B1,C3 اي زاوية ميلان ٥ درجة و معدل تغذية ٠,٠١ و سرعة دوران ١٢٠٠ دورة بالدقيقة. كذلك بالنسبة لمعدن البرونز فان الظروف كانت A1,B1,C3 اي زاوية ميلان ٥ درجة و معدل تغذية ٠,٠١ و سرعة دوران ١٢٠٠ دورة بالدقيقة.