PREDICTION OF SURFACE ROUGHNESS IN TURNING MACHINE Using TAGUCHI METHOD

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ABSTRACT

This paper investigates the effect of process parameters (approach angle, nose radius, cutting speed and feed rate) on surface roughness in turning machine. The experiments was conducted based on Taguchi's L_8 orthogonal array and assessed with analysis of variance and signal to noise ratio. According to this, it was observed that surface roughness correlates negatively with nose radius and positively with approach angle. The ability of the independent values to predict the dependent values was 95.1% for mean. Minimum surface roughness was predicted as 4.207 µm with approach angle 5°, nose radius 1.5mm, cutting speed of 455 rpm and feed rate of 0.19 mm/rev. From analysis of variance ANOVA, the feed rate was the most significant parameter for minimum surface roughness, cutting speed was next significant parameter for minimum surface roughness, then nose radius, while approach angle was the last.

Keywords: Surface roughness, turning, taguchi method, ANOVA, nose radius.

التنبؤ بالخشونة السطحية في عملية الخراطة باستخدام طريقة تاكوجي

الخلاصة:

يهدف البحث على التعرف على تاثير اعتبارات التشغيل مثل (زاوية الاقتراب ، نصف قطر مقدمة الحد القاطع، سرعة القطع ومعدل التغذية) على الخشونة السطحية في عملية الخراطة. الاختبارات اجريت بالاعتماد على تاكوجي L8 كمصفوفة عمودية يتم تقييمها مع تحليل التباين ونسبة الاشارة الى الضوضاء. طبقا" الى هذا يلاحظ ان الخشونة السطحية ترتبط سلبيا" مع نصف مقدمة الحد القاطع وايجابيا" مع زاوية الاقتراب. قابلية القيم المستقلة على التنبؤ بالقيم المعتمدة كانت 95.1% . ان اقل خشونة سطحية متنبأة كانت4.207 مايكرومتر مع زاوية اقتراب 5 درجة ،نصف قطر مقدمة حد قاطع 1.5 ملم،سرعة قطع 455 دورة بالدقيقة و معدل تغذية 0.19 ملم/دورة.من تحليل التباين كان معدل التغذية هو الاكثر تأثير لأقل خشونة سطحية ,سرعة القطع كانت هي المتغير الثاني الذي يؤثر على اقل خشونة سطحية , ومن ثم نصف قطر مقدمة الحد القاطع, بينما زاوية الاقتراب كانت الاخيرة من ناحية التأثير على الخشونة السطحية.

1- INTRODUCTON:

Metal cutting is one of the most significant manufacturing processes in the area of material removal [Chen, 1997]. Black defines metal cutting as the removal of metal from a workpiece in the form of chips in order to obtain a finished product with desired attributes of size, shape, and surface roughness [Black, 1979]. Turning is the processes used to remove material to produce specific products of high quality. Among various process conditions, surface finish is central to determining the quality of workpiece [Shin, 1995] .The tool edge geometry has an important influence on the process parameters, such as the cutting forces, distributions of temperature and stresses on the tool face and the chip morphology. These effects in turn affect the changes in chip flow, machined surface integrity, tool wear resistance, and tool life [Yen, 2004].

The various angles in a single-point cutting tool have an important function in machining operations. Cutting-edge angles affect chip formation, tool strength and cutting forces to various degrees [Jones, 1999]. Cutting condition in a machining operation consist of cutting speed, feed rate and depth of cut. The effects of cutting speed and feed rate on the surface roughness are different with deferent change in cutting condition and materials [Shin, 1995, Hatem, 2011]. The surface roughness depending upon the cutting condition, essentially the cutting speed, the change of cutting speed give different results with increasing the cutting speed leads to improvement in the surface finish of turning process. The second factor which effected upon the surface roughness is feed rate, because of the elastic and plastic deformation on the surface layer reducing the feed rate helps to a chive a better surface quality. While the change in the depth of cut gives a less effect on the surface roughness, than on the cutting speed and feed rate [Shin, 1995, Kalpakjian, 2006, Groover, 2002]. The tool nose radius is very critical part of the cutting edge since it produces the finished surface, if the nose is made to a sharp point the finish machined surface will usually be unacceptable and the life of the tool will be short[Mccauley, 2000]. If other factors such as the work material, the cutting speed, and cutting fluids are not considered large nose radius will give better surface finish and will permit a faster feed rate to be used [Trent, 1984]. Avery large nose radius can often be used but a limit is some times imposed because the tendency for chatter to occur is increased as the nose radius is made larger prove that most cutting conditions , experimental and theoretical (Ra) values mach very well, except at low value of feed .Also one of the structural modes of the machine tool – workpiece system is excited by cutting forces initially away surface finish left during the previous revolution in turning is removed during the succeeding revolution which also leaves a wavy surface owing to structural vibrations[Shather, 2009]. Taguchi method has been widely used in engineering analysis, and is a powerful tool to design a high quality system. Moreover, Taguchi method employs a special design of orthogonal array to investigate the effects of the entire machining parameters through small number of experiments. The array forces all experimenters to design almost identical experiments [Brar, 2011].

In the present research determination the effect of process parameters approach angle and nose radius for cutting tool, cutting speed and feed rate for turning machine on surface roughness in turning machine and then predict for surface roughness by using taguchi method.

2. EXPERIMENTAL PROCEDURE:

2.1 Material:

The workpiece used in this work was made of stainless steel with dimensions of 150mm length and 40mm width. The chemical compositions are shown in table 1.

2.2 Machine:

The experiment was performed by using a Turning Machine model (Harrison M300) as shown in Figure 1.

2.3 Cutting tool:

The cutting tool was made of carbide, used with different approach angle (Table 2); this carbide has triangle shape and used three carbides insert with deferent nose radius (Table 2) as shown in Figure 2.

2.4 Process parameters:

The machining parameters, such as approach angle, nose radius, cutting speed and feed rate were varied to determine their effects on the surface roughness with fixed depth of cut at 1mm. The experiments were designed to study the effects of these parameters on response characteristics. Table 2 shows the various levels of process parameters.

3- ANALYSIS BY TAGUCHI METHOD:

The experiments were planned by using the parametric approach of the Taguchi's Method. The response characteristic data was provided in Table 3. The standard procedure to analyze the data based on S/N ratio, as suggested by Taguchi, was employed. The average values of the S/N Ratio of the quality/response characteristics for each parameter at different levels were calculated from experimental data. The response parameters (surface roughness), are of "smaller is the better" type of machining quality characteristics; hence the S/N ratio for these types of responses was given by equation (1) [Gupta, 2011].

$$S/N = -10\log\left[\frac{1}{n}\sum_{i=1}^{n}(y_i^{\,2})\right] \qquad ; \qquad i=1, 2, \ldots\ldots\ldots n \qquad (1)$$

Where n: number of reading test.
y_i: output variable value (R_a).

3.1 Taguchi orthogonal array:

One of the basic elements of Taguchi method is Orthogonal Array (OA). To select an appropriate orthogonal array for the experiments, the total degrees of freedom need to be computed. The degrees of freedom are defined as the number of comparisons between process parameters that need to be made to determine which level is better and specifically how much better it is [Gupta, 2011]. There is minimum number of experimental trials required in orthogonal array, so it is more efficient in handling large number of factor variables than traditional factorial design. Additionally, the orthogonal array allows determination of the contribution of each quality influencing factor [Tongchao, 2010]. In the present research, the standard Taguchi orthogonal array of L_8 (4^1 x 2^3) has been employed.

3.2 Analysis of variance ANOVA:

The ANOVA is used to investigate the statistical significance of the process parameter affecting the response. Therefore, the factor that has more percentage contribution in the process will be identified in analysis. The ratio between the variance of the process parameter and of the error called as F test determines whether the parameter has a significant effect on the quality characteristic. The larger F-value has more effect on the performance characteristics [Chomsamutr, 2012]. ANOVA table obtained using Minitab program.

4- RESULTS AND DISCUSSION:

Table 3 represents the experimental results of various response Characteristics according to Taguchi L_8 mixed orthogonal array. Surface roughness for each experiment is measured using portable surface finish tester. Various response characteristics, namely, Ra in micrometers. The average (mean) of these characteristics and S/N ratio (in decibels) are shown for each characteristic. The R Square pieces (the ability of the independent values to predict the dependent values) is 95.1% for mean (surface roughness).

The main purpose of the analysis of variance (ANOVA) is to investigate and indicate the designed parameters, which significantly affect the quality characteristic. In the analysis, the sum of the square deviation is calculated from the value of S/N ratio by separating the total variability of S/N ratio for each control parameter.

This analysis helps to find out the relative contribution of finishing parameter in controlling the response of this process. The “P%” value (percent of contribution) in Tables 4 and 5 shows the effectiveness of each parameter toward influencing the related response characteristics within the specified range. From Table 4, it is concluded that the feed rate (parameter D) is the most significant parameter for minimum Ra. cutting speed (parameter C) is next significant parameter for minimum Ra , then nose radius (parameter B), while approach angle (parameter A) was the last.

From Table 5, it is concluded that the cutting speed (parameter C) is the most significant parameter for maximum S/N ratio. Feed rate (parameter D) is next significant parameter for maximum S/N ratio, then nose radius (parameter B) , while approach angle (parameter A) was the last.

Figures 3and 4 shows the plot of the means of the surface roughness and the means of S/N ratio. It is clear that the optimal parametric combination for minimum Ra is A_1 B_2 C_1 D_2, i.e., at 5° approach angle, 1.5mm nose radius, 355 rpm cutting speed and 0.19mm/rev feed rate. It is suggested that the parametric combination within the considered range as mentioned above give lowest surface roughness height Ra for finishing of workpiece.

5- CONCLUSIONS:

The main conclusions deduced from the present work can be summarized as follows:

1- The ability of the independent values to predict the dependent values) is 95.1% for mean.

2- The feed rate (parameter D) is the most significant parameter for minimum Ra.

3- The cutting speed (parameter C) is the most significant parameter for maximum S/N ratio.

4- The optimal parametric combination for minimum Ra is A_1 B_2 C_1 D_2, i.e., at 5° approach angle, 1.5mm nose radius, 355 rpm cutting speed and 0.19mm/rev feed rate.

5- The optimal parametric combination for S/N is A_1 B_2 C_1 D_2, i.e., at 5° approach angle, 1.5mm nose radius, 355 rpm cutting speed and 0.19mm/rev feed rate.

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Table (1): Chemical compositions of workpiece. [AISI]

Element	Cr%	Ni%	P%	Mn%	C%	Fe%
Weight	11.5	0.03	1.0	0.5	0.15	Remain

Table (2): Process Parameters at Different Levels

No.	**Parameter**	**Level 1**	**Level 2**	**Level 3**	**Level 4**
1	**Approach angle(degree) A**	5	10	15	20
2	**Nose radius (mm) B**	0.5	1.5	/	/
3	**Cutting speed (rpm)** C	355	455	/	/
4	**Feed rate (mm/rev) D**	0.16	0.19	/	/

Table (3): The L_8 (4^1x2^3) OA (Parameters Assigned) with experimental results of various response Characteristics.

No	**A**	**B**	**C**	**D**	**R_{a1}(μm)**	**R_{a2}(μm)**	**R_{a3}(μm)**	**S/N**	**R_a Mean(μm)**	**R_a Predict(μm)**
1	5	0.5	355	0.16	4.32	4.65	4.56	-13.0877	4.51	4.41125
2	5	1.5	455	0.19	3.98	4.33	4.05	-12.3038	4.12	4.21875
3	10	0.5	355	0.19	5.25	5.41	4.64	-14.1697	5.10	5.19875
4	10	1.5	455	0.16	4.87	4.96	5.77	-14.3463	5.11	5.10125
5	15	0.5	455	0.16	5.01	5.42	5.50	-14.5090	5.31	5.40875
6	15	1.5	355	0.19	5.32	5.10	5.09	-14.2716	5.17	5.07125
7	20	0.5	455	0.19	5.29	5.22	5.48	-14.5364	5.33	5.23125
8	20	1.5	355	0.16	5.12	4.78	4.77	-13.7910	4.89	4.98875

Table (4): Analysis of Variance for mean Taguchi Orthogonal Array (TOA)

Source	**Degrees of Freedom DF**	**Sum of Squares SS**	**Mean Sum of Squares SS**	**Mean Square MS**	**F value (MS /error)**	**Percent of Contribution P**
A	3	1.07345	1.07345	0.357817	5.84	0.293
B	1	0.11520	0.11520	0.115200	1.88	0.401
C	1	0.00500	0.00500	0.005000	0.08	0.823
D	1	0.00125	0.00125	0.001250	0.02	0.910
Residual Error	1	0.06125	0.06125	0.061250		
Total	7	1.25615				

Table (5): Analysis of Variance for SN ratios Taguchi Orthogonal Array (TOA)

Source	**Degrees of Freedom DF**	**Sum of Squares SS**	**Mean Sum of Squares** SS	**Mean Square MS**	**F value (MS /error)**	**Percent of Contribution P**
A	3	3.64678	3.64678	1.21559	5.59	0.299
B	1	0.38238	0.38238	0.38238	1.76	0.411
C	1	0.00561	0.00561	0.00561	0.03	0.899
D	1	0.01025	0.01025	0.01025	0.05	0.864
Residual Error	1	0.21743	0.21743	0.21743		
Total	7	4.26246				

Figure (1): Turning Machine model (Harrison M300)

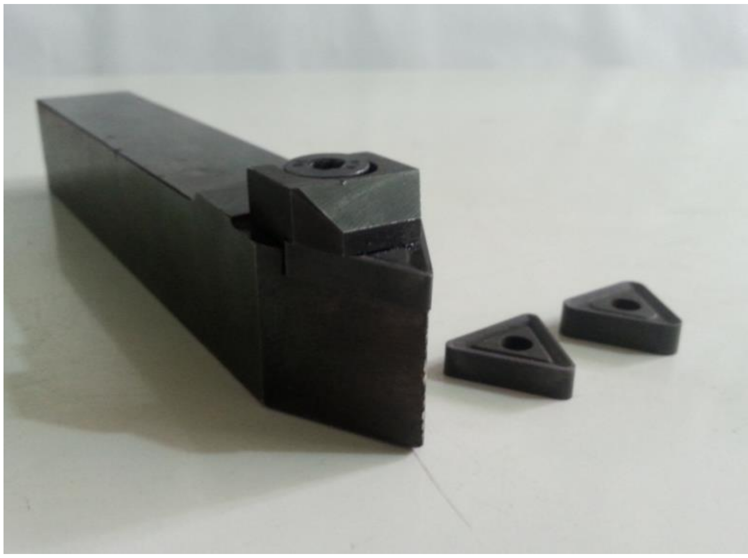

Figure (2): Holder and insert

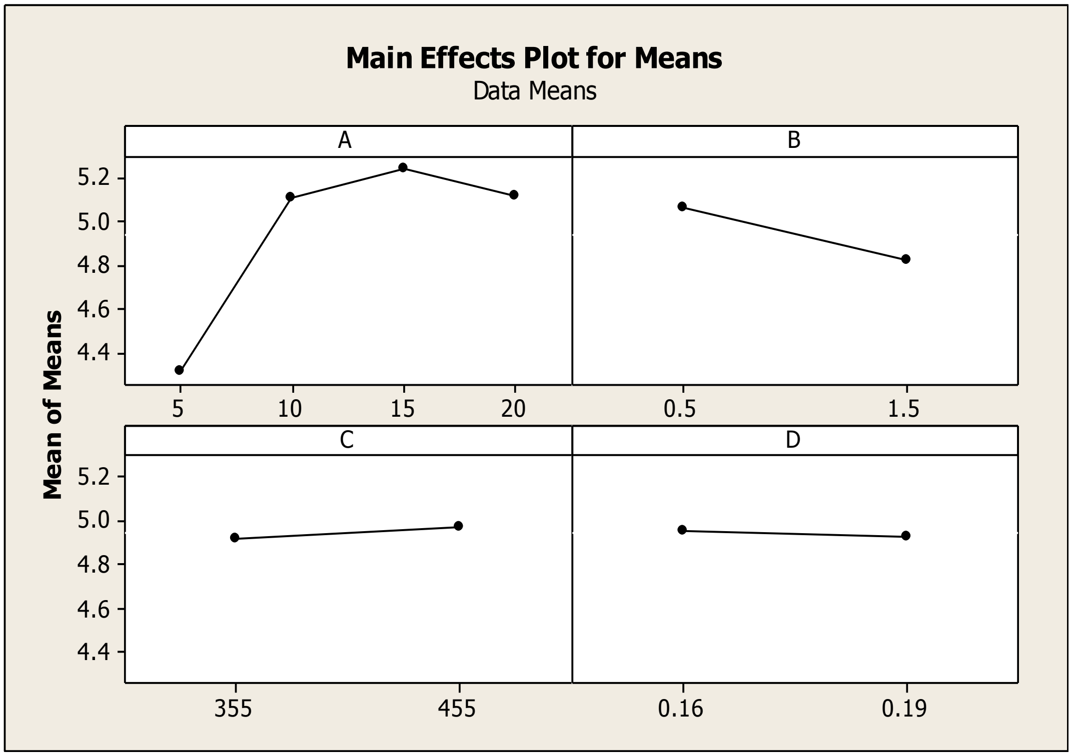

Figure (3): Main effects Plot for means

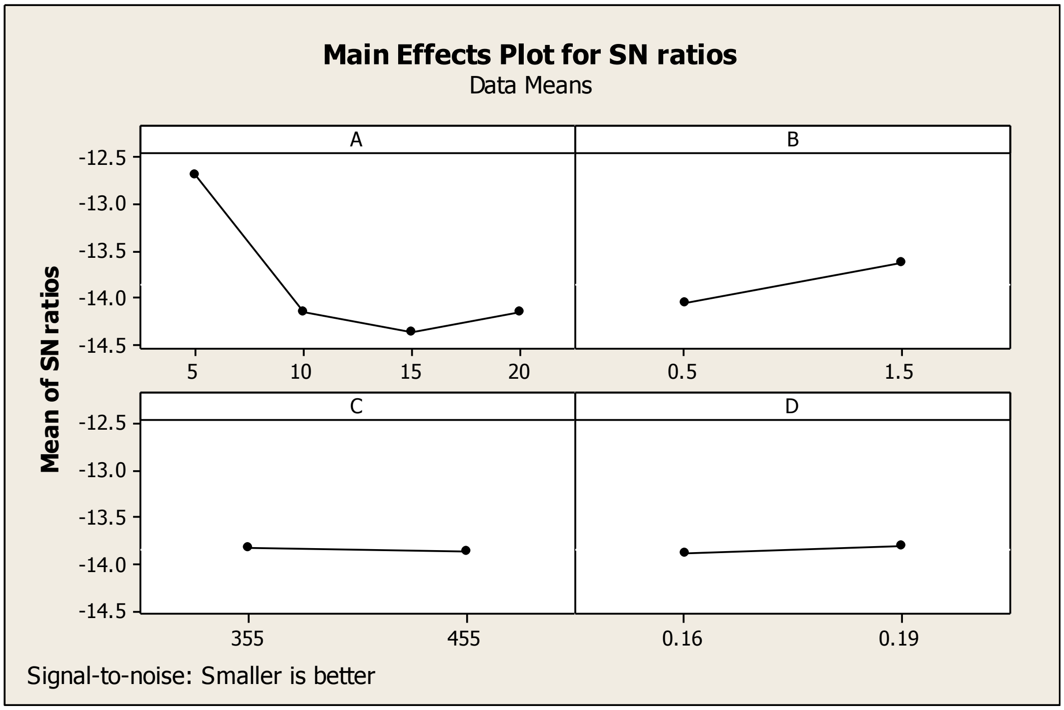

Figure (4): Main effects Plot for signal to noise ratios