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Establishing Into The Effect Of The Grinding Condition On The Productivity And Quality

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Abstract

This study investigated to find the relationship between productivity and quality of surface for difference grinding conditions, to develop a better understanding of the effect of cutting conditions for grinding, on the surface roughness and productivity, to build a multiple regression models and exponential models. Such an understanding can provide insight into the problems of controlling the surfaces finish with productivity when the process parameters are adjusted to obtain a certain surface finish at the acceptable productivity. There are three various machining parameters have an effect on the quality and productivity such as the velocity of detail (υ, m/min), feed rate (f, mm/min) and the cutting time (τ, min) for different diameters of work piece, that are known to have a large impact on surface quality and productivity. The results of experiment allow considering the establishing grinding condition on the productivity and quality of surface, and then obtain mathematical models to ensure the quality and productivity. The goal of this work is to identify a relationship between experimental results and theoretical model, and establishing the proper process values for cylindrical grinding, to increasing the rates for raising the productivity of the process. Application of new progressive rates of correct grinding condition, it is very benefit when using in practice. In order to maximize the gains from utilizing finish surfaces, accurate mathematical prediction models are finding by using least squares estimation method, which includes the effect of grinding conditions predicted the surface roughness values with an accuracy of about 10%, and 12% for productivity. The analysis of the effects of various parameters shows that the feeds and cutting speeds have significant effects in reducing the surface roughness, while the working time has the least effect. So the analysis reveals that the cutting speed and cutting time have significant effect in the rising the productivity, while the feed has the least effect.

KEY WORDS: Cylindrical grinding, Surface roughness, Productivity, Mathematical model, Cutting speed, feed ate, working time.

الخلاصة

تَحرّتْ هذه الدراسةِ لإيجاد العلاقةِ بين الإنتاجية و جودة السطح لمختلف ظروف القطع بالتجليخ لأظهار مفهوم أفضل عن تأثير نظام القطع في عملية التجليخ ثم تنظيم العلاقة بين جودة السطح و الأنتاجية. هناك ثلاثة عوامل تشغيلية مُخْتَلِفة تؤثر على الإنتاجية و جودة السطح مثل سرعةِ القطع (υ)، التغذية (f) والوقت التشغيل (τ) ِ ولعينات مختلفة الأقطار ، ذلك لمعرفة تأثيرها الكبير على الإنتاجية و جودة السطح . النتائِج التجريبيةِ توضح حالة التجليخ على الإنتاجية و جودة السطح, وبعد ذلك يتم الحصول على النماذج الرياضية لضمان النوعيةِ ومعدلِ الإنتاج. إنّ هدفَ هذا العملِ أنْ يُميّزَ علاقة بين النَتائِجِ التجريبيةِ والنموذج النظريِ، ويُؤسّسُ لقيم صحيحة لعمليةَ التجليخ الاسطوانية،لأجل رفع الانتاجية.

هذة القيم التَصاعُديةِ الجديدةِ لشروط التجليخ الصحيحةِ، وهي مفيدة جداً في التطبيقات العملية. لكي يُزيّدَ المكاسبَ مِنْ إسْتِعْمال سطوح ذات تشطيب نهائي.،تم ايجاد نماذج تنبؤ رياضيةِ دقيقةِ ُ بإستعمال طريقةِ تقدير المربعاتِ الصغرى. تحليلَ دِراسَة تأثيراتِ تفاعلَ مختلف المتغيرات تشير الى أن التغذية وسرعة القطع لَهُما تأثيراتُ هامّةٌ في التَخفيض من النعومة السطحيّةِ ، بينما الوقت لَهُ أقلّ التأثير. كما تشير التحاليل بأن سرعة القطع والوقت لهما التأثير الأكبر في رفع الأنتاجية, بينما التغذية لها التأثير الاقل .

Introduction:

In cylindrical grinding, similarly to other metal cutting processes, the applied speed of detail and feed rates must be adjusted to the operational conditions as well as to the objectives of the process. The surface quality is an important parameter to evaluate the productivity of machine tools as well as machined components. Hence, achieving the desired surface quality is of great importance for the functional behavior of the mechanical parts [1]. Surface roughness is used as the critical quality indicator for the machined surface and has influence on several properties such as wear resistance, fatigue ,strength, coefficient of friction, lubrication, wear rate and corrosion resistance of the machined parts [2], also the productivity is an important which have considerable effect on the time and cost. Quality and productivity can be achieved only through proper cutting condition. This paper attempts to obtain mathematical models of surface roughness (Ra) and productivity (Q) for cylindrical grinding.

The progress in the development of predictive model, based on cutting theory, has not yet met the objective; the most essential cutting performance measures, such as, roughness of grinding surface, productivity, energy consumption, …etc., should be defined using experimental studies. Therefore, further improvement and optimization for the technological and economic performance of grinding operations depend on a well-based experimental methodology. Unfortunately, there is a lack of information dealing with test methodology and data evaluation in metal cutting experiments [9].

Several factors influence the final surface roughness in grinding operation. Factors such as cutting speed, feed rate, and working time that control the cutting operation can be setup in advance. However, factors such as tool geometry, tool wear, and chip formation, or the material properties of both tool and work piece are uncontrolled [10].

The values of surface roughness stated on the manufacturing constructions cannot be realized without a good combination between the preferred grinding parameters **(**υ, f, and τ) during the process of manufacturing. In all manufacturing methods, besides the high productivity, a satisfactory quality of surface roughness is very important. The occurrence of surface roughness is affected by lot of factors like cutting speed, feed and cutting time [3, 4, and 5]. The technological engineers used their own experience and machining guidelines in order to achieve the best possible surface finish at high productivity. Due to inadequate knowledge of the complexity and factors affecting the surface finish, an improper decision may cause high production cost and low quality. The proper selection of grinding condition for achieving a proper grinding performance is a critical task.

Experimental Method And Materials:

Experiments have been performed in order to establishing into the effect of many factors of the process parameters (υ, f, and τ) of the grinding on the productivity and quality. Surface roughness (Ra) measured in micro-meters with a profilometer, and the weigh in grams they are the response variables. The same machine was used for all experimental work, and the same operator grinds all specimens.

The material used in this study was hardened steel; the hardness was measured to 40HRC. Cylindrical shaft with an outer diameter (D1= 47.5, D2= 47.53, D3= 47.61mm).the wheel velocity 45 m/sec, coolant equal 10.5 Litter/min, scale graduation of weighting equal 0.001. The width of the shaft was 35mm, surface roughness were measured by profile- meter tester. Table 1 list the test condition cutting speeds and feed were selected to span the range of condition recommended by reference [6]. Table 2 is matrix plan. The experiment executed according to the following steps:

1. Surface roughness and difference weights test executed three times for each samples. Then the mean value obtained.
2. The experiment conducted according to the matrix plan, 2^n, and table 2.
3. Repeat the steps 1, 2 for each specimen.

Table 1 the Level of the Factors

Level	**limit**	**υ , m/min**	***f*, mm/min**	**τ, min**
base	0	40	0.106	0.25
High	+1	60	0.2	0.40
Low	-1	20	0.012	0.10
interval	Δχί	20	0.094	0.15

Table 2 matrix plan,2^n, and results

№	**$Z_1(f)$**	**$Z_2(υ)$**	**$Z_3(τ)$**	**Ra/mkm**	**Q/N/min**
1	-	-	-	0.3346	0.00110
2	+	-	-	0.6160	0.00107
3	-	+	-	0.4000	0.00758
4	+	+	-	0.7031	0.00954
5	-	-	+	0.3330	0.00230
6	+	-	+	0.5980	0.00275
7	-	+	+	0.3810	0.02460
8	+	+	+	0.6775	0.02570

Regression based Modeling

In order to know the surface quality and productivity, it is necessary to employ theoretical models making it feasible to do prediction in function of operation conditions [11]. Response surface methodology (RSM) is a collection of mathematical and statistical techniques that are useful for the modeling and analysis of problems in which a response of interest is influenced by several variables and the objective is to optimize this response [7].

The exponential models for surface roughness and productivity as a function of cutting speed (υ), feed (*f*) and the cutting time (τ)[11],

$Ra = C_o\, υ^{c1}\, f^{c2}\, τ^{c3}$ …………………………………………………….. (1)

$Q = C_o\, υ^{c1}\, f^{c2}\, τ^{c3}$ ……………………………………………….……. (2)

Multiple linear regression models for surface roughness and productivity can be obtained by applying a logarithmic transformation that converts non- linear from equation (1, 2) respectively into following mathematical form:

$\ln Ra = \ln C_o + C_1 \ln X1 + C_2 \ln X_2 + C_3 \ln X_3$ …………………….……..(3)
$\ln Q = \ln C_o + C_1 \ln X_1 + C_2 \ln X2 + C_3 \ln X_3$ ………………..……….. (4)

This regression analysis technique using least squares estimation was applied to compute the coefficients of the exponential model by using the sparse experimental data, generated by [7] for cylindrical grinding.
(Volume)$V = \pi D \ell h$ (D- diameter of shaft, ℓ- working width, h- thickness)
(Weight) $w = V \gamma$ (γ- specific density)
$w = \pi D \ell h \gamma$
Productivity (Q) = $\frac{wieght(w)}{time(\tau)}$ N/min
$\bar{y}i = \frac{1}{N}\sum_{i=1}^{N} yji$ …………………………………..……………… (5)
N =3 (three repeated sample)
The mean value for repeated experiments can find by[ ]
$\bar{Q}i = \bar{y}i = \frac{1}{N}\sum_{i=1}^{N} \bar{Q}i$ ……………………………..…………… (6)
Disperse for each group experiments can find by formula.
$S_i^2 = \frac{1}{N-1}\sum_{i=1}^{N}(y_{ji} - \bar{y}_i)^2$ …………………………………………… (7)
$s^2\{Q\} = \frac{\sum_{i=1}^{n} Si^2}{n}$ ……………………………..………… (8)
n = 4(number of experiment in the same conditions)
To compute the coefficients of the exponential model by using the following formula:
$\beta_o = \frac{1}{n}\sum_{i=1}^{n} \bar{y}i = \frac{\sum_{i=1}^{n} \ln \bar{Q}i}{n}$ ………………..………………….(9)
$\beta_i = \frac{\sum_{i=1}^{n} \ln \bar{Q}i\, Zij}{n}$ ……………………………………………...(10)
Zij (From matrix plan table 2), the equations can be rewritten as
$y = \beta_o + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \varepsilon$ ……………………….…….… (11)

Were y is the logarithmic value of the measured surface roughness, β_o, β_1, β_2, β_3 are regression coefficients to be estimated X_o is the unit vector X_1, X_2, X_3 are the logarithmic values of cutting speed, feed and time, ε is the random error[7]. The following linear models are for surface roughness and productivity, the result of the above equations are determined by [8], and are given, respectively.

The final response equations in terms of actual factors are given as:
$\mathbf{Ra = -0.727 + 0.071\,\upsilon + 0.292\,f - 0.015\,\tau}$ ……………………..… (12)
$\mathbf{\bar{Q} = -5.31 + 1.09\upsilon + 0.0531\,f + 0.481\,\tau}$ …………………………… (13)

The exponential models for surface roughness and productivity can be obtained by applying a logarithmic transformation that converts linear form equation (12, 13) respectively into the following models (forms).

$$X_i = \frac{2(\ln Xi - \ln Ximax)}{\ln Xi\max - \ln Ximin} + 1 \quad \text{…………………………………..…….. (14)}$$

For cutting speed, feed and time for example to find the value of cutting condition

$$\upsilon = \frac{2(\ln \upsilon - \ln \upsilon max)}{\ln \upsilon\max - \ln \upsilon min} + 1$$

$$f = \frac{2(\ln f - \ln fmax)}{\ln f\max - \ln fmin} + 1$$

$$\tau = \frac{2(\ln \tau - \ln \tau\, max)}{\ln \tau\max - \ln \tau\, min} + 1$$

The developed response surface roughness, within the experimental region is as:

$$\mathrm{Ra} = \frac{\upsilon^{0.13}\, f^{0.207}}{1.82\quad \tau^{0.0216}} \quad \text{…………………………………..………… (15)}$$

The developed response productivity, within the experimental region is as:

$$Q = e^{-11.18}\, \upsilon^{2.00}\, f^{0.037}\, \tau^{0.692} \quad \text{…………….…..……………… (16)}$$

Result And Discussion:

The exponential models (15, 16) for surface roughness and productivity are compared with the experimental data sets and they are shown in Fig 1 and 2. It was possible to establish exponential relationships between the surface roughness's (Ra) and productivity (Q) when grinding under the different conditions (s1 to s8). This relationship is useful for process control and optimization. The numerical estimates of the effects indicate that the effect of cutting feed is largest $(f^{0.207})$ and has positive direction means that the surface finishes deteriorated with increasing the cutting feed see fig 2. The cutting speed also has positive effect ($\upsilon^{0.13}$), which indicates that decreasing the speed improves the surface finish, and the effect of cutting speed is less significant on the surface finish.

Equation (15) shows the effect of working time ($\tau^{-0.0216}$), the negative direction means that increasing the working time improves the surface finish. While the effect of cutting speed is the largest (16)and has positive direction($\upsilon^{2.00}$) means that the productivity increased with increasing the cutting speed. It is generally known that an increase in cutting speed improves machineability. The working time ($\tau^{0.692}$) also has positive, which indicates that increasing working time, increasing the productivity.

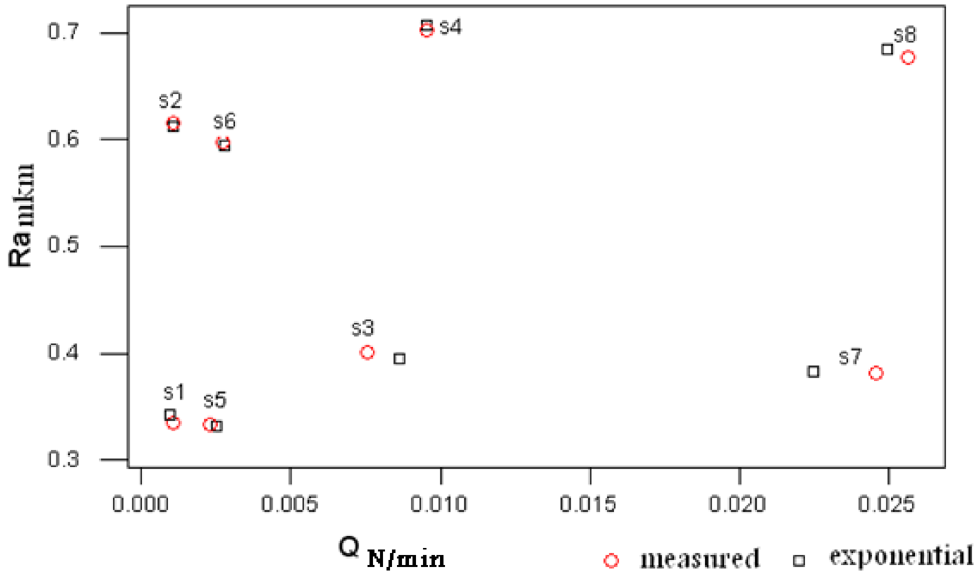


Fig. 1. The Relationship Between Quality And Productivity At Different Grinding Conditions

s1- υ = 20 m/min; ƒ = 0.012 mm/min; τ = 0.1 min
s2- υ = 20 m/min; ƒ = 0.2 mm/min; τ = 0.1 min
s3- υ = 60 m/min; ƒ = 0.012 mm/min; τ = 0.1 min
s4- υ = 60 m/min; ƒ = 0. 2 mm/min; τ = 0.1 min
s5- υ = 20 m/min; ƒ = 0.012 mm/min; τ = 0.4 min
s6- υ = 20 m/min; ƒ = 0.2 mm/min; τ = 0.4 min
s7- υ = 60 m/min; ƒ = 0.012 mm/min; τ = 0.4 min
s8- υ = 60 m/min; ƒ = 0.2 mm/min; τ = 0.4 min

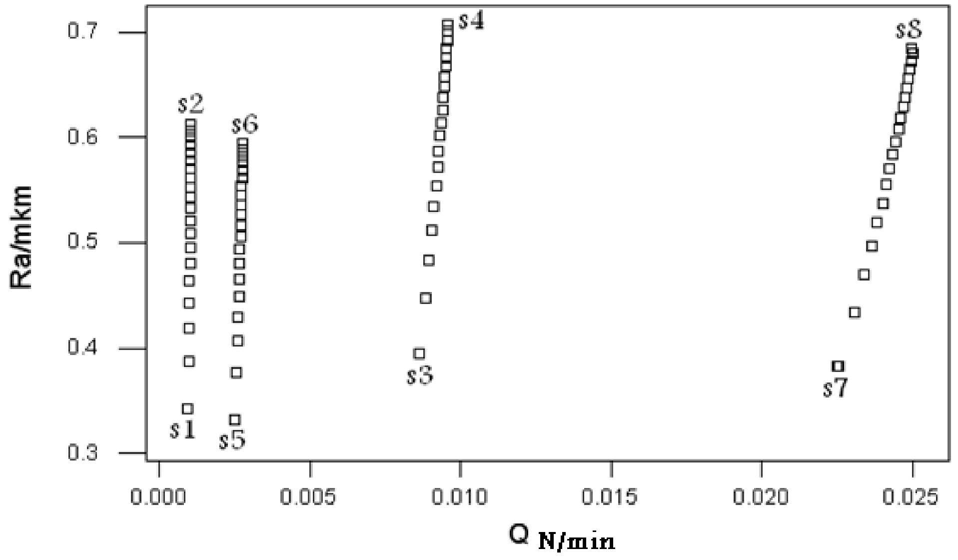


Fig. 2.The Relationship Between Quality And Productivity At Different Cutting Feeds

The feed rate ($f^{0.037}$) has less effect on the productivity. In Fig 2, each cluster represents one cutting condition with difference cutting feed. Relatively good results obtained at s1, s5, s3, s7 when low values for cutting feed. Good productivity at cutting condition s7, at the expense of the quality of the surface. Good quality at cutting condition s5 is at the expense of productivity and time, the different between the two cutting conditions is the cutting speed. If the quality and productivity importance, It can control the cutting speed to find the better condition by using the exponential models, in the first step choose the proper quality (Ra) then choose minimum feed rate as possible, the second step find the productivity by controlling the cutting speed and working time.

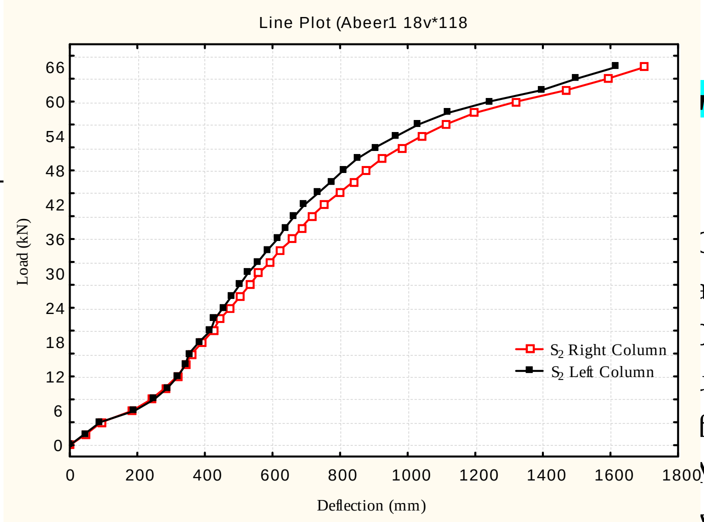
Conclusions:

A series of experiments has been conducted in order to characterize the factors affecting surface roughness and productivity for grinding. The models generated, which includes the effect of cutting speed, feed rate, and working time. The deviation between predicted and measured value was within an error band of about 10 -12%.

Based on the experimental and analytical result, the following conclusions are drawn:

1. In general, the study shows that the feed rate is by far the most dominant factor for surface roughness then the cutting speed, while the working time has little effect.
2. The cutting speed is the dominant factor for productivity followed by the working time, while the feed shows minimal effect on the productivity.
3. The effect of grinding factors on the quality and productivity has been established with the help of mathematical models, the optimal grinding conditions to minimize the surface roughness and maximize the productivity have been determined.

Using such models, one can obtain a remarkable saving time and cost.



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