Study the Effect of Cutting Conditions for turning process on the Machined Surface

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Abstract:

Surfaces quality is one of the most specified customer requirements for machine parts. The major indication of surfaces quality on machined parts is surface roughness. The research aim is to study the cutting conditions and their effects on the surface roughness. This paper utilizes regression models to predict surface roughness over the machining time for variety of cutting conditions in turning. In the experimental part for turning, different types of materials (Aluminum alloy, Copper alloy, and Gray cast iron) were considered with different cutting speed (υ) and feed rate (f).

A mathematical Model depending on statistical-mathematical method between surface roughness (Rz) and cutting condition (υ , f) were derived, for the three materials.

The matrix of test conditions included cutting speeds of the 16, 30, 45 and 60 m/min, feed rates of 0.17, 0.35 and 0.7 mm/rev while the depth of cut has been kept constant. The effect of cutting parameters on surface roughness is evaluated and the optimum cutting condition for minimizing the surface roughness is determined. Mathematical model has been established between the cutting conditions and surface roughness using regression. The predicted values and measured values are fairly close, which indicates that the developed model can be effectively used to predict the surface roughness in the turning machining. As the results of this work, the mathematical models were used in predicting surface roughness, can be used in CAD-CAM manufacturing systems, this mathematical model helps engineer to reduce the efforts.

Mathematical models shows that the decreasing in the feed rate resulted in better surface roughness and increasing cutting speed resulted in better surface roughness. The goal of this work is to identify a relationship between experimental results and theoretical model, and study the proper process values for machining, to increasing the rates for raising the quality (better surface roughness).

KeyWords: surface roughens, cutting condition, mathematical model, different material,turning process, cutting speed, feed rate.

Introduction

Metal cutting is one of the most significant manufacturing processes in the area of material removal [1]. 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 [2]. 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 a workpiece [3].

The surface parameter used to evaluate surface roughness in this study is the Roughness Average, Ra or Rz. This parameter is also known as the arithmetic means roughness value, arithmetic average (AA), or centerline average (CLA). Ra or Rz is recognized universally as the commonest international parameter of roughness, as defined by the following equation [4]:

$$Rz = \frac{1}{5}\left[\sum_{i=1}^{5}|yp| + \sum_{i=1}^{5}|yv|\right] \quad (1)$$

Rz-surface roughness for five profile peaks.
yp- profile peak.
yv- profile valleys.

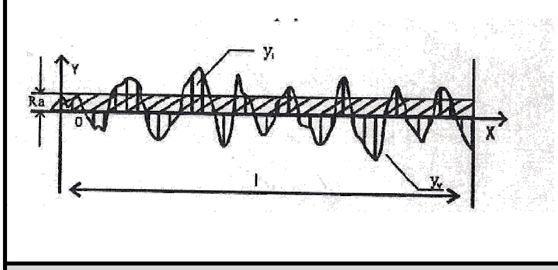

Fig.1 - Simple diagram explain the average of the sum of maximum profile peaks

and the average of minimum profile valleys within the sampling length [4].

It is necessary to understand the relationship among the various controllable parameters and to identify the important parameters that influence the quality of turning. Moreover to get good surface quality and dimensional properties, it is necessary to employ optimization techniques to find optimal cutting parameters and theoretical models to do predictions. In the present study, effect of cutting parameters on surface roughness on the turning machine is evaluated and second order model is developed for predicting the surface roughness. The predicted and measured values are fairly close to each other. Their proximity to each other indicates the developed model can be effectively used to predict the surface quality.

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 [3,4].

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 [3, 5, 6].

Varying both the cutting speed and feed in machining workpiece, these varying lead to arrange and help to relate the cutting conditions, and this gives effects on workpiece which influence to surface layers of parts. The criteria of effective parts after machining use the quality of surface, which defined by the surface roughness, determined by (Rz) the height of profile roughness over 10 points [3, 1, 7, 8, 9].

Selection of Cutting Conditions

The effectiveness of turning process can be determined by the effects of surface layer and depend upon three parameters of cutting conditions have been chosen which are cutting speed, feed rate and three different materials (different hardness) at constant depth of cut (0.5mm).

1. v = 16, 30, 45, 60 m/min (cutting speed).
2. f = 0.17, 0.35, 0.7 mm/rev (feed rate).
3. Three materials (different hardness) the Brinell hardness was measured in the Engineering Manufacturing Operation Department -University of Baghdad :-
   - Gray cast iron – 240 BHN.
   - Aluminum alloys –160 BHN.
   - Copper alloy –120 BHN.

These three parameters have different effects on forming surfaces and the amount of stresses on the layer of workpiece. The ability of guiding these parameters v, f, BHN for working material to get the optimum values will help for finding the surface roughness Rz, and analytical expression will be determined [1, 6].

Experimental Method and Materials

A set of experiments designed to begin the characterization of surface quality for the turning process have been performed. The objective of this study is to develop a better understanding of the effects of cutting speed, feed rate and different materials at constant depth of cut (0.5mm) on the surface roughness and to build a multiple regression model. Such an understanding can provide insight into the problems of controlling the finish of machined surfaces when the process parameters are adjusted to obtain a certain surface finish [9, 10, 11, 12, 13].

An experimental was conducted using lathe machine (The MYSORE KIRLOKAR LTD, India, 1330 Model, the round speed n = 90-1200 rpm) with variable speed of spindle and different longitudinal feed rate for three materials.

The high speed steel was used as cutting tool in process. The surface roughness Rz was measured by surface roughness instrument (profile meter) with suitable cut off length 0.8 represented on average of the sum of five maximum profile valleys within the sampling length [9], surface roughness tester was in Manufacturing Eng. Department then the experiment conducted according to the matrix in table (1), the surface roughness test executed three times for each samples by using instrument, then the mean value of ΔRz obtained, the values of ΔRz for all samples are record in table (2)., after that repeat the steps for each sample.

To test the effect of the three parameter of cutting condition on the effectiveness of the working operation and specify the effectiveness relationships of the turning process, experiments must be executed because the finished surfaces have more than one parameter at some time, a plan must be use to obtain the relationship which explain the combination between the main parameters.

Table (1) Matrix parameters-cutting cond.		
No. of experimental	*v* (m/min)	*f* (mm/rev)
1	16	0.17
2	16	0.35
3	16	0.7
4	30	0.17
5	30	0.35
6	30	0.7
7	45	0.17
8	45	0.35
9	45	0.7
10	60	0.17
11	60	0.35
12	60	0.7

Table (2) Final results according to matrix parameters		
Criteria ΔRz µm for gray cast iron	Criteria ΔRz µm for Aluminum alloys	Criteria ΔRz µm for copper alloys
31.04	26.37	15.12
37.041	32.567	30.21
85.13	37.6	38.34
28.16	20.949	11.676
35.295	24.26	23.26
80.013	40.66	39.34
24.73	12.59	11.09
25.81	27.17	20.14
70.71	35.51	31
8.6	5.09	5.856
9.11	8.12	8
9	7.97	7

Regression based Modeling

Researchers [3, 6, 8] indicates that the relations, characteristics cutting process, can be expressed empirical relation's, which descript as second degree function [12, 13]:-

$$y = Ax^m \quad (1)$$

By logarithm the expression gives:-

$$\log y = \log A + m \log x \quad (2)$$

If takes $Rz = f(v) = A_{1Rz} v^{yRz}$ at *f* and t = const.

$Rz = f(f) = A_{2Rz} f^{yRz}$ at *v* and t = const.

The relation between Rz and *f(v) and f(f)* will be written :-

$$Rz = Cv^{\alpha} f^{\beta} \quad (3)$$

$$\log Rz = \log C + \alpha \log v + \beta \log f \quad (4)$$

Used:- $\log Rz = l$

$\log v = x, \log f = y, \log C = z$

Then:- $l = \alpha x + \beta y + z$

By least square method.

$\sum_{i=1}^{n} (yi - A - Bx_{i)}) = 0$ n = number of experiment

To find the minimum used partial differentiation to A and B and put the equation equal to zero.

$$-2\sum_{i=1}^{n} (yi - A - Bxi) = 0$$

$$nA + B\sum_{i=1}^{n} xi = \sum_{i=1}^{n} yi$$

$$A\sum_{i=1}^{n} xi + B\sum_{i=1}^{n} xi = \sum_{i=1}^{n} yixi$$

By Solving this system equation:-

$$B = \frac{n\sum_{i=1}^{n} x_i y_i - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} y_i}{n\sum_{i=1}^{n} (x_i)^2 - \sum_{i=1}^{n} (x_i)^2}$$

$$\alpha\sum\log v + \beta\sum\log f + n\sum\log c = \sum\log R_Z \quad (5)$$

$$\alpha(\sum\log v)^2 + \beta\sum\log f \log v + n\sum\log v \log c = \sum\log v \log R_Z \quad (6)$$

$$\alpha\sum\log v \log f + \beta\sum\log f^2 + n\sum\log f \log c = \sum\log f \log R_Z \quad (7)$$

Fore cast iron finding:-

$$18.3603\alpha - 5.5212\beta + 12\log c = 18.3503 \quad (8)$$

$$31.7427\alpha - 8.39723\beta + 18.33795\log c = 27.68735 \quad (9)$$

$$-8.39723\alpha + 3.2952\beta - 5.5212\log c = -7.8618 \quad (10)$$

By Solving this equations:-

$\alpha = 0.1043$

$\beta = 0.776$

$c = 53.301$

In the final stage finding that:-

- $R_Z = 53.3 v^{0.1043} f^{0.776}$ ----- for cast iron

And by the same method finding the relations:-

- $R_Z = 21.7852\, v^{0.0918} f^{0.4382}$ ------------------- for Aluminum alloy

- $R_Z = 64.108\, v^{0.2029} f^{0.6033}$ --------------------- for Copper alloy

Results and discussion

The Effect of Cutting Speed and feed rate on the Surface Roughness

From experiments, surface roughnesses were obtained according to the (Table-1 & Table-2).The curves shown in Fig.(2) was obtained for cast iron. The results show that the increase cutting speeds and feed rate cause unequal surface roughness, and that seen in Fig.(2), (3), (4).. Also for different materials in the same cutting condition (same cutting speed and feed rate) gives different Rz according to characteristic of materials.

A low hardness material ductile material gives (Rz) more than the high hardness brittle materials at high cutting speed, at the low feed rate. The experiment shows that the change of cutting speed (v) at different cutting feed (f) gives the same relationship, in general.

The first case, when the feed rate f = 0.7 mm/rev large the curve gives the best roughness near the cutting speed 60 m/min for the three materials. Then decreasing the cutting speed lead the surface roughness to increase.

In the second case, when the feed rate f = 0.35 mm/rev (less than first case), the curves show with increasing the cutting speed to 45 m/min the roughness increase, increasing the cutting speed to 60 m/min and more gives better roughness.

In the third case, when the feed rate f = 0.17mm/rev, the curves gives the best surface roughness for the three materials. Decreasing feed rate lead to better surface roughness. for the three materials, increasing the cutting speed lead to better surface roughness, decreasing the hardness of material lead to improve the surface roughness fig.(5).

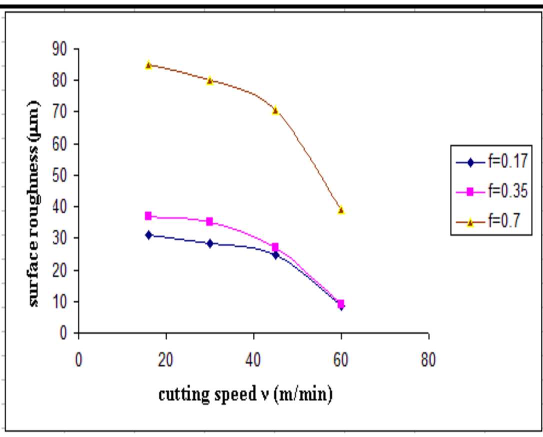

Fig. (2) - Relationship between cutting speed and Surface roughness fore cast iron

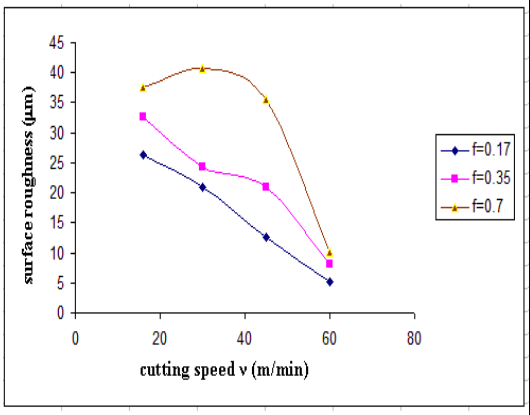

Fig. (3) - Relationship between cutting speed and Surface roughness for aluminum alloy

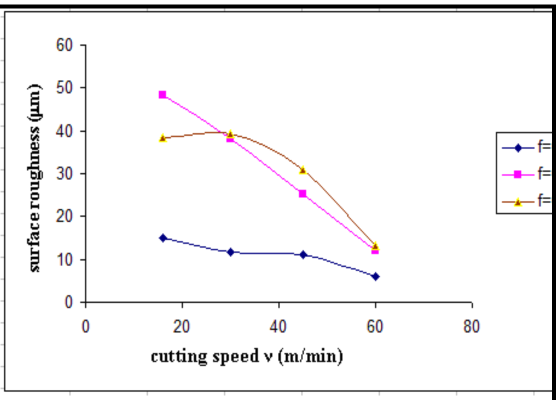

Fig. (4) - Relationship between cutting speed and Surface roughness for copper alloy

(Fig. 5, 6, 7) shows the change of surface roughness for different cutting conditions (cutting speed and feed rate) and the effect of hardness (three materials) on it.

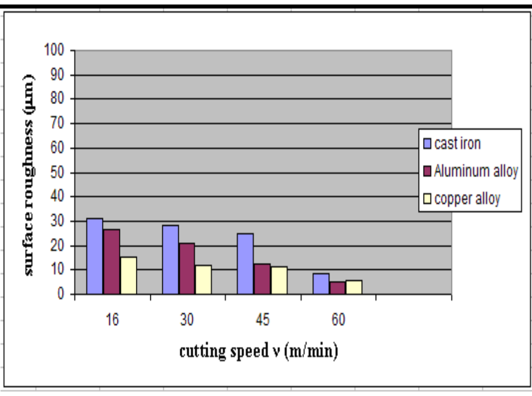

Fig. (5) - The relation between *v* and Rz for three materials at
f = 0.17 mm/rev
BHN $_{Fe}$ > BHN $_{Al}$ > BHN $_{Cu}$

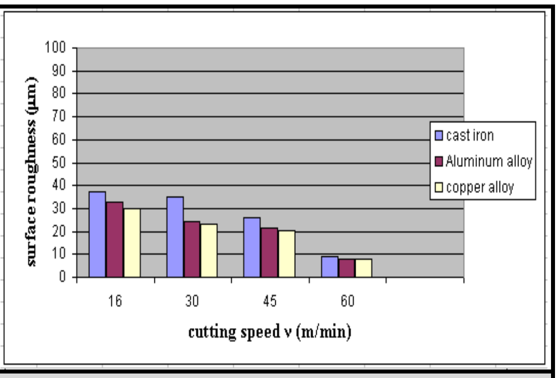

Fig. (6) - The relation between *v* and Rz for three materials at
f = 0.35mm/rev
BHN $_{Fe}$ > BHN $_{Al}$ > BHN $_{Cu}$

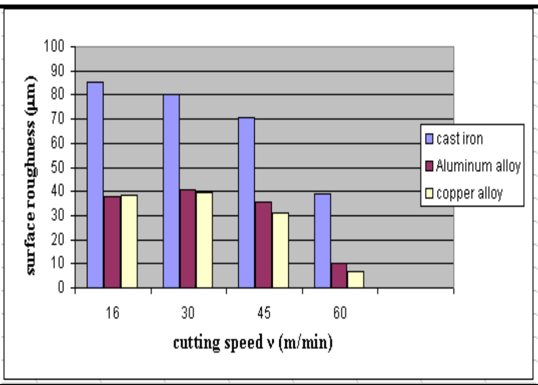

Fig. (7) - The relation between *v* and Rz for three materials at
f = 0.7mm/rev
BHN $_{Fe}$ > BHN $_{Al}$ > BHN $_{Cu}$

Conclusions

The results of experiments allow considering the establishing cutting condition on the quality of surface, and then obtain mathematical models to ensure the quality. In order to maximize the gains from utilizing finish surfaces, accurate mathematical prediction models are finding by using least squares method, which includes the effect of cutting conditions predicted the surface roughness values with an accuracy of about 10-15%.

The analysis of the effects of various parameters shows that the cutting speeds have significant effect in the reducing roughness and feed rate have second effects in reducing the surface roughness, while the working materials has the least effect.

The models generated, which includes the effect of cutting speed, feed rate, and working materials.

Finally the most important points are:-

1. In general, the study shows that the cutting speed is by far the most dominant factor for surface roughness then the feed rate, while the working materials has less effect.
2. The effect of cutting condition on the quality has been established with the help of mathematical models, the optimal conditions to minimize the surface roughness has been determined.

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دراسة تأثير الشروط القاسية لمنعطف العملية على سطح المكائن

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الخلاصة

إن أحد أهم متطلبات أجزاء المكائن هي جودة السطوح، إن المؤشر الرئيسي لجودة السطوح عند تشغيلها هي خشونة السطح (Ra أو Rz). فكرة البحث هي دراسة متغيرات ظروف القطع وتأثيرها على خشونة السطح. البحث استخدم نموذج الرياضي للتنبوء بجودة السطح خلال فترة تشغيل لعملية الخراطة ولمختلف ظروف القطع.

في الجزء العملي تم دراسة أنواع مختلفة من المواد (سبيكة ألمنيوم، سبيكة نحاس، حديد زهر) حيث اعتمدت سرع قطع مختلفة وتغذيات مختلفة. في البحث تم الحصول على نموذج رياضي- إحصائي (موديل) بواسطة طريقة إحصائية رياضية لوضع علاقة بين خشونة السطح وسرعة القطع والتغذية، فقد تم في الجزء العملي اخذ سرع قطع مختلفة (16, 30, 45, 60) م/دقيقة مع قيم تغذية مختلفة (0.17 – 0.35 – 0.7) ملم/دورة مع ثبوت عمق القطع (0.5) ملم . إن تأثير ظروف القطع على خشونة السطح ستقدر مع شروط القطع المثالية للحصول على اقل خشونة ممكنة للسطح. القيم التي تم الحصول عليها من الموديل الرياضي كانت متقاربة جدا مع القيم المختبرية. إذا من أهم النتائج هو الحصول على موديل رياضي يساعدنا على التنبوء بجودة السطح ويمكن الاستفادة من هذا الموديل في أنظمة التصنيع المؤتمتة وبدون العودة الى المراجع مما يقلل من الجهد والوقت في حساب واختيار نظام القطع المناسب. الموديل يبين أنه كلما تقل التغذية كلما تكون خشونة السطح أفضل، وأن زيادة سرعة القطع تعطي خشونة سطح أفضل.

ان الهدف مما تقدم هو تحقيق العلاقة بين النتائج التجريبية والموديل الرياضي والقيم العملية التشغيلية المناسبة لزيادة إمكانية الحصول على أعلى جودة (خشونة سطح أفضل).