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Predictive Modeling of Surface Roughness Of Centered And Un-Centered Workpiece Lengths In Turning Operation

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Abstract

The attempt of the present study has addressed an area that has been relatively neglected in the past researches. This area focuses on studying and analysis the effect of different centered and un-centered workpiece lengths, using turning machine tailstock, on the products surface roughness, and then collecting data to generate an experimental charts and equations for the prediction modeling of surface roughness and increasing productivity for many turned products. These charts and equations could be serving as a quick indication for manufacturers to avoid pre-chatter conditions and the trial and error methods, and consequently reduce the required experience in this field. So, the applicable range of workpiece lengths can be safely extended from 10 mm to 60 mm bars with 10 mm in diameter, and from 10 to 75 mm bars with 20 mm in diameter. This range could be increasing as bar diameter increasing and vise versa.

Keywords: Surface Roughness, Predictive Modeling, Tool Geometry

نمذجة التنبؤ بالخشونة السطحية لأطوال عينات ممركزة وغير ممركزة مشغلة بالخراطة

الخلاصة

إن الدراسة الحالية تتناول مساحة بحثية مهملة نسبياً في البحوث السابقة، حيث تركز هذه المساحة على دراسة وتحليل مقدار تأثير تغير أطوال عينات ممركزة وغير ممركزة، باستخدام الغراب المتحرك، على قيم الخشونة السطحية للمنتجات المشغلة بالخراطة. ومن ثم جمع البيانات اللازمة لأنشاء المخططات والموديلات الرياضية الناتجة عن مجموعة من التجارب العملية لغرض التنبؤ بالأنهاء السطحي للمنتجات وزيادة الأنتاجية للعديد من المشغولات المنتجة بالخراطة. هذه المخططات والموديلات الرياضية يمكن أن تستخدم كمؤشر سريع للمشغلين لتلافي ظروف الأصطكاك وعمليات التجربة والخطأ وبالتالي تقليل الخبرة اللازمة في هذا المجال.عليه فان مدى أطوال العينات التطبيقي الآمن يمكن أن يمتد من 10 ملم الى 60 ملم بالنسبة للأعمدة ذات قطر10 ملم، ومن 10 ملم الى 75 ملم بالنسبة للأعمدة ذات قطر 20 ملم، ويزداد هذا القطر مع زيادة قطر العمود والعكس بالعكس.

Introduction

Metal cutting is one of the most significant manufacturing processes in the area of material removal. Black (1979) defined metal cutting as the

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removal of metal chips from a workpiece in order to obtain a finished product with desired attributes of size, shape, and surface roughness [1].

Turning is a manufacturing process in which a workpiece is held, and usually centered by the machine tailstock, and rotated about its longitudinal axis on a machine tool called a lathe. Cutting tools mounted on the lathe are fed into the workpiece to remove material and thus produce the required shape [2].

The quality of machined workpiece is evaluated by how closely they adhere to set product specifications of length, width, diameter, surface finish, and reflective properties. Among various process conditions, surface finish is central to determining the workpiece quality.

In turning operation, there are numerous machining factors that affect surface quality. Some of these factors can be controlled and some can not. Controllable process parameters include feed, cutting speed, tool geometry, and tool setup. Other factors, such as tool, workpiece and machine vibration can not be controlled as easily [3].

Some Related Works

There are variety of works which have been done in the area of the relation between turning workpieces and their surface finish. The study of Mandara D. and Joseph C. [4] aims to identify significant effects of tool diameter on tool vibration and workpiece surface roughness in end mill cutting. The data collected demonstrates that tool diameter has a significant effect on vibration generation and surface roughness. Workpiece vibration and surface roughness were significantly affected by the feed rate of the cutting tool. The interaction between tool diameter and feed rate have a significant effect on Ra and Vibration data; however, that effect was largely due to feed rate. Results of this study show that tool diameter should be considered as a major contributing factor in the surface roughness recognition model.

Ozel T. and Karpat Y. (2005) [5] have developed a neural network modeling to predict surface roughness and tool flank wear over the machining time for variety of cutting conditions in finish hard turning. Regression models are also developed in order to capture process specific parameters. A comparison of neural network models with regression models is also carried out.

Predictive neural network models are found to be capable of better predictions for surface roughness and tool flank wear within the range that they had been trained. Predictive neural network modeling is also extended to predict tool wear and surface roughness patterns seen in finish hard turning processes. Decreasing in the feed rate that resulted in better surface roughness but slightly faster tool wear development, and increasing cutting speed resulted in significant increase in tool wear development but resulted in better surface roughness. Increasing in the workpiece hardness that resulted in better surface roughness but higher tool wear.

A detailed experimental investigation is presented by Ozel T., Hsu T. and Zeren E. [6] for the effects of cutting edge preparation geometry, workpiece surface hardness and cutting conditions on the surface roughness and cutting forces in the finish hard turning of AISI H13 steel. The results have indicated that the effect of cutting edge geometry on the surface roughness is remarkably significant. The cutting forces are influenced not only by cutting conditions but also the cutting edge geometry and workpiece surface hardness.

This study shows that the effects of workpiece hardness, cutting edge geometry, feed rate and cutting speed on surface roughness are statistically significant. The effects of two-factors interactions of the edge geometry and the workpiece hardness, the edge geometry and the feed rate, and the cutting speed and feed rate are also appeared to be important.

The attempt of Doniavi A., Eskadarzade M., and Tahmasebian M. [7] is to develop an imperical model with the use of response surface methodology that is widely adapted tool for the quality engineering field. The established predictive model shows that the feed rate was found to be main influencing factor on the surface roughness. It is increased with the increasing the feed rate. But decrease with the increasing cutting speed.

The study of Kassab S. and Khoshnaw Y. [8] is to find a correlation between surface roughness and cutting tool vibration in turning. The data is generated by lathe dry turning of medium carbon steel samples at different levels of parameters. Dry cutting tests (without using cutting fluid) are conducted to simulate a good turning, the dry turning provided a clean environment to obtain undisturbed clear cutting vibration, which results in more accurate and clear correlation between cutting vibrations and roughness. The analysis of variance reveale in this study is that the best surface roughness condition is achieved at a low feed rate, less and equal 0.13mm/rev, and with smaller tool overhang, less and equal 30mm. The results also show that the cutting speed has small effect on surface roughness than feed rate and tool overhang. The depth of cut has not a significant effect on surface roughness in this study.

Theoretical Model of Surface Roughness

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

$$R_a = \frac{1}{L}\int_0^L \left|Y(x)\right| dx \qquad \ldots\ldots (1)$$

Where L is the sampling length and Y is the ordinate of the curve of the profile, the arithmetic mean of the departure of the roughness profile from the mean line [4].

Experimental Investigation

Experimental Setup

The practice of choosing appropriate process parameters can be quite difficult, and requires time consuming trial and error experimentation which is costly in time and material resources.

The present work planned and carried out in such a way to provide detailed chart of information on the effect of variation of a set of centered and un-centered workpiece lengths on the turning products surface finish. The materials and equipment were used in the experimental procedure of this investigation are; the workpiece material type used is cold drawn low carbon steel bars shape with variable dimensions as shown in figure (1). While the machining equipment used in this study is all commonly available, which include Celtec Germany turning machine, a surface roughness tester model TR200 was used to measure surface roughness. This surface roughness measuring device is the most widely used instrument in industry and research laboratories, because it is computerized, fast, consistent, easy to use, and relatively inexpensive.

Experimental Procedure

In this study, a set of experiments done to study the physical effect of variation of centered, using machine tailstock, and un-centered workpiece lengths on turning products surface finish. The reason of using this approach was to investigate and identify the allowable and safe workpiece length where the surface roughness values of the un-centered workpieces were statistically compared with centered workpieces.

As noted before, cold drawn low carbon steel bars shape was used for the workpiece material. This particular material was chosen specifically because of its wide-spread use in turning operations, and also because it would be beyond the scope of this research to involve all materials at this level.

A set of nineteen pairs of workpiece bar lengths were evaluated independently, of centered and un-centered machining, at the particular bar length being studied with the range (10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, and 100 mm), as shown schematically in figure (1). All these specimens were machined using a cutting speed of 1000 RPM, 0.8 mm was the depth of cut, 0.1 mm / rev feed rate and 26 mm tool overhang, used for all trials.

As mentioned earlier, this study seeks to evaluate whether difference of workpiece length affects the surface roughness. When determining the parameters for testing this effect, spindle speed, depth of cut, and type of work material remained constant.

Results and Discussion

After nineteen pair of specimens were machined for experimental purposes, they were measured off-line with a predefined stylus type profilemeter to obtain the roughness average value.

Figure (2) and (3) show graphically the resulted surface roughness of a pair of nineteen specimens, with variant lengths graduated from 10 mm to 100 mm with a step of 5 mm, for both centered and un-centered workpieces with 10 and 20 mm diameter respectively. The resulted charts are usually based on experience and many trial and error operations to obtain suitable cutting data for such cutting operation involved in machining a product.

According to the experimental obtained results, the diverted characteristic of the centered workpiece, for both 10 and 20 mm bars diameter, curve relationship is small and could be neglected.

It is worth noting that due to the non-linear characteristic of the obtained un-centered workpiece results for both 10 and 20 mm bars diameter, the mathematical representation of the equation that best fits the acquired results are given by the following:

$$Ra_{10} = 0.0016\ WL^2_{10} - 0.0903\ WL_{10} + 1.9263 \quad \ldots\ldots (2)$$

$$Ra_{20} = 0.0007WL^2_{20} - 0.0484WL_{20} + 1.3952 \quad \ldots\ldots (3)$$

Where (WL_{10}) and (WL_{20}) present the physical un-centered workpiece length in (mm) units for 10 mm and 20 mm bars diameter respectively, (Ra_{10}) and (Ra_{20}) present the acquired surface roughness in (µm) units for 10 mm and 20 mm bars diameter respectively.

Two particular trends were appear in the graphs, the centered workpieces values move in relatively stable trajectory which is produce acceptable regions of surface roughness. While the un-centered workpieces values, with 10 mm diameter, begin to move in un upward trajectory, suggesting in increasing instability within the system. This trajectory is decreasing as workpiece diameter increasing as shown in the graph of 20 mm bars diameter.

Conclusions

The goal of the present research is to investigate the effects of different lengths of centered and un-centered workpieces to develop an experimental reference machining equation to serve as a quick indication for manufacturers to avoid pre-chatter conditions, the trial and error methods, and consequently reduce the required experience in this field.

Results of this study show that the workpiece lengths should be considered as a major contributing in the surface roughness of turned products and thus, the developed equations are used in predicting surface roughness for various different workpiece lengths, and the obtained results validate the original premise of equal surface roughness in some regions of workpiece length when comparing centered and un-centered turning operations.

So, the applicable range of workpiece lengths can be safely extended from 10 mm to 60 mm bars with 10 mm in diameter, and from 10 to 75 mm bars with 20 mm in diameter. This range could be increasing as bar diameter increasing and vise versa.

Using the same workpiece material, the obtained comparison chart can be broadened to include a wide range of diameters and lengths applicable to this particular material.

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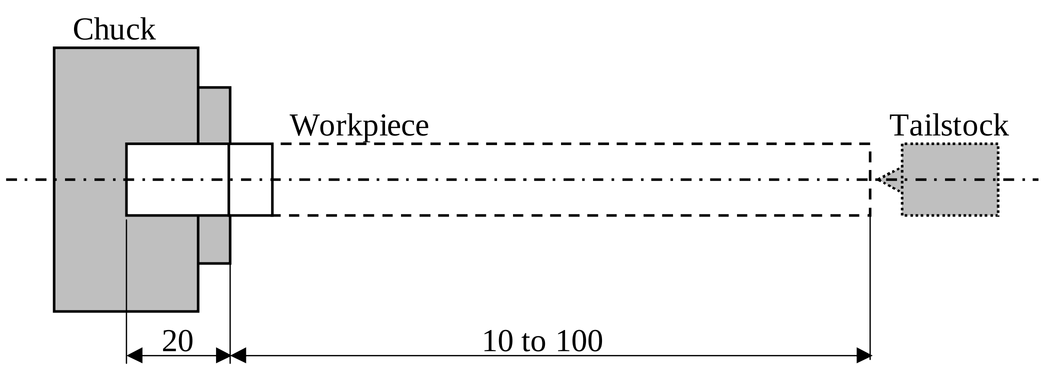

Figure (1) Workpiece Dimensions (all dimensions are in mm unit)

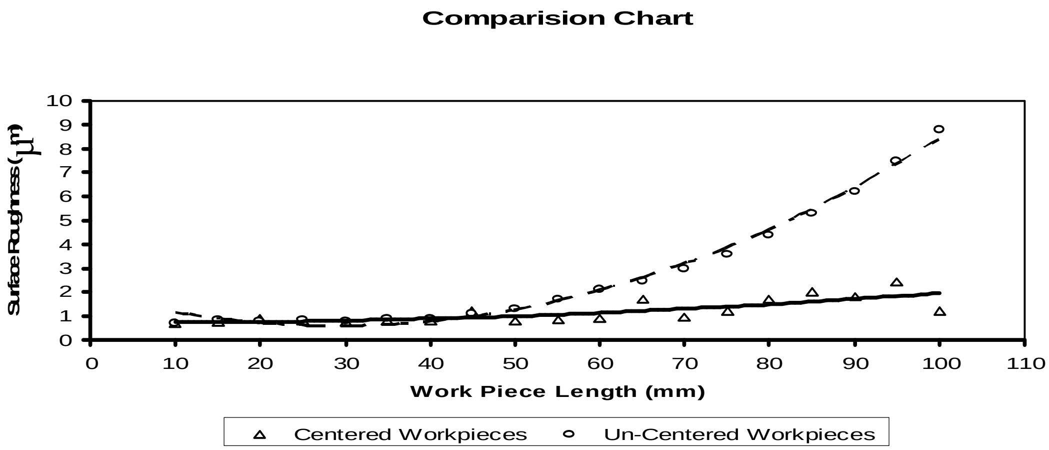

Figure (2) Results of variant workpiece lengths vs. surface roughness For 10 mm workpiece diameter

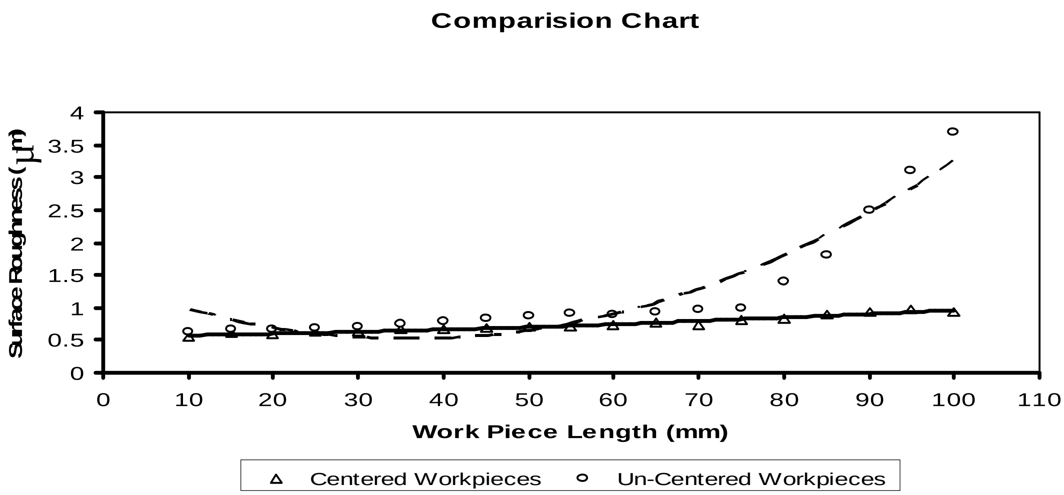

Figure (3) Results of variant workpiece lengths vs. surface roughness For 20 mm workpiece diameter