EFFECT OF CUTTING PARAMETERS ON SURFACE ROUGHNESS IN TURNING OPERATIONS

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ABSTRACT: -

Surface roughness is an important criteria of the product quality in the machining operations. It is depends on cutting parameters. The objective of this research is to investigate experimentally the influence of cutting parameters on the surface roughness in turning operation, in order to determine the optimal settings of these parameters to improve surface roughness in the turning operations.

In this work, surface roughness was measured for steel turned components, which was carried out on a conventional and on a computer numerically controlled (CNC) turning machine with carbide tool at different cutting parameters such as; cutting speed, depth of cut, feed, and the usage of cutting coolant.

The experimental results were collected and analyzed. The relation between cutting parameter and surface roughness were determined. The experimental results show that the turned component surface roughness is significantly influenced by the cutting parameters, usage of cutting fluid, and the machine tools. The results obtained from this work show that the surface roughness of the turned components decreased by increasing spindle speed and it increased by increasing depth of cut and feed, while it decreased by using cutting fluid.

Also the results show that the surface roughness for the turned components on the CNC machine was less than on the conventional machine using the same cutting parameters.

تأثير ظروف القطع على الخشونة السطحية في عملية الخراطة

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الخلاصة:
ان خشونة السطح هي من المعايير المهمة لجودة المنتج في أي عملية تشغيل بالقطع, وهي تتأثر بعوامل عملية القطع. الهدف من هذا البحث هو إجراء تجارب عملية للتوصل الى معرفة تأثير ظروف القطع على خشونة السطح في عملية الخراطة من أجل تحديد الإعدادات المثلى لهذه العوامل وذلك لتحسين خشونة السطح في عملية الخراطة.

في هذا البحث قد تم قياس خشونة السطح لعينات الصلب بعد عملية الخراطة التي قد أجريت على ماكنة خراطة تقليدية وعلى اخرى تعمل تحت سيطرة الحاسوب (CNC) باستعمال اداة قطع كربيدية عند ظروف قطع مختلفة كسرعة القطع, عمق القطع و التغذية واستخدام سوائل القطع.

لقد تم جمع نتائج التجارب و تحليلها, وتم تمثيل العلاقة بين ظروف القطع و خشونة السطع بيانيا, وتمت المقارنة بين النتائج العملية, حيث تبين أن خشونة سطح تتأثر بشكل كبير بظروف القطع و باستخدام سوائل القطع, وتعتمد كذلك على ماكنة القطع. حيث بينت النتائج ان الخشونة السطحية للعينات الناتجة من عملية الخراطة قلت زيادة سرعة القطع, وازدادت بزيادة عمق القطع و التغذية وقلت عند استخدام سوائل التبريد.

وقد بينت النتاج كذلك, ان الخشونة السطحية للعينات الناتجة من عملية الخراطة على ماكنة الخراطة التي تعمل تحت سيطرة الحاسوب (CNC) كانت اقل منها للعينات التي تمت خراطتها عل ماكنة الخراطة التقليدية و باستخدام نفس ظروف القطع.

Nomenclature:

R_t: peak-to-valley surface roughness,
K: main cutting angle,
K': auxiliary cutting angle
r: tool nose corner radius, and
f: feed.

Keywords: Surface Roughness, cutting speed, feed, cutting coolant, CNC Machine.

INTRODUCTION:

Surface roughness is a predominant characteristic in evaluating surface quality of the machined component (P.N. Rao, 2000), which is included in the machining drawing. It’s usually related to correct performance of a part. Hence, obtaining good surface quality is required in most machining applications, so that it has a vital role in influencing the customer satisfaction in manufacturing, however machined surface quality demands significantly affect cost of production and increase the price of a product. Surface roughness is affected by many factors in machining process. Machined components during their useful life are significantly influenced by surface roughness which affects several properties such as; corrosion resistance and fatigue strength, wear resistance, coefficient of friction, ability of distributing and holding a lubricant, load bearing capacity, heat transmission, and coating (C. Natarajan et al., 2011). Therefore, control of the machined surface roughness is essential (Ilhan Asiltürk et al., 2011), and appropriate processes parameters have to be selected to reach the desired surface quality machined parts.

Surface roughness is measured by the vertical deviations of a real surface from its horizontal ideal form. If these deviations are relatively large, the surface is rough; if they are relatively small, the surface is smooth (Hassan, 2014).

Turning is the most common method in machining processes (Kanase et al., 2013). In turning operation, the surface roughness of the machined surface is a result of combination effect of both of ideal and natural roughness's. Ideal roughness is due to the feed marks. It follows the cutting edge and side cutting edge with same intersection which may be sharp ended or rounded as shown in figure **(1)**. It can be modeled and predicted from the cutting tool geometry as shown in Eq. (1) for the tools with sharp intersection of the main and auxiliary cutting edges; however, cutting tool with round corner nose is more common because it helps with smoother surface finish nose. Eq. 2 represents the ideal surface roughness when using cutting tool with round corner nose tool (Steven et al., 2016).

$$R_t = \frac{f}{\text{Cot } K + \text{Cot } K'} \qquad (1)$$

$$R_t = \frac{f^2}{32\, r} \qquad (1)$$

The theoretical ideal surface roughness will not be exact as the real surface roughness under conditions of finish machining when the feed is very small (W. Grzesik, 1996), this is due to; plastic deformation in the cutting zone extended to the machined surface, after-machining elastic recovery of the machined surface material, and adhesive interaction between the chip and the side cutting edge (J. Kaczmarek, 1976). The amplitude of the ideal roughness can eliminated by overlapping cuts by re-cutting the final tool path without any change in the feed and with zero depth of cut (S. Vajpayee, 1981).

The natural roughness is correlated to the other machining parameters that is difficult to predict such as; properties of the workpiece material, cutting velocity, rigidity of the machine tool and vibrations, and built up edge formation.

Vibrations within the system can have an obvious effect on the surface roughness of a machined component. This vibration is related directly to the stiffness and damping capacity of the machine - tool - workpiece clamping system. Cutting operations generate two basic types of vibrations; the forced vibrations which are usually caused by a periodic force present in the machine tool, such as an unbalanced in rotating masses, misalignment, etc., and the Self-excited vibration (chatter) which is caused by the interaction of the chip removal process and the structure of the machine tool (Mathew A., 2010).

Built-up edge formation in chip removal process is one of the major sources of surface roughness. At relatively low speeds where the temperature is relatively low, a built-up edge starts to be formed in the metal cutting zone on the tool face and grows until it reaches a critical size then separates and passes over with the chip. This gives a cyclic variation in the built-up edge size. Since the built-up edge grows outward and downward, this makes variation in depth of the cut surface which represents a major component of surface roughness. As cutting speed increases, the size of the built-up edge decreases. This is due to lower flow stress at the interface than in the main body of the chip (Milton C., 2005). The chip variation which is related to the built-up edge formation acts as a dynamic force excites tool vibrations, and has significant effect on surface roughness (M. Thomas et al., 1996). Since the built-up edge formation depends whether dry machining is performed or coolant is being used, and the proper cutting speed is used or not, it is expected that natural roughness to vary with actual cutting speeds (Posinasetti, 2000), and because cutting tool vibrations are mainly influenced also by other cutting parameters like; depth of cut and tool feed in addition to cutting speeds (S. S. Abutlhakeer et al., 2011), then with properly chosen cutting conditions the vibration may be avoided. Some of the recommended suggestions to reduce vibration and chatter are as follows: More rigid structure and a higher damping capacity in designing the machine tool, properly orienting the workpiece, proper clamping and minimizing overhang. Most of the modern CNC machine tools manufactured recently have excellent stiffness and damping capacities when installed and calibrated appropriately (M. Ramalinga Reddy et al., 2012).

EXPERIMENTS:

In this study, 27 steel specimens were used of 50 mm diameter and 50 mm length as shown in figure **(2)**, was machined on a conventional turning machine without cutting fluid, and using carbide tools with the grade of P-30. In the firs stet of experiments the cutting speed were changed to the magnitude of (100, 200 and 500 rpm) while feed was fixed at (0.064 mm/rev.) and the depth of cut at (1mm). In the second set of experiments the depth of cut were changed to the magnitude of (1, 1.5 and 2 mm) while cutting speed was fixed at (160 r.p.m.) and the feed at (0.05 mm/rev.). In the third set of experiments the feed were changed to the magnitude of (0.18, 0.23 and 0.35 mm/rev.) while cutting speed was fixed at (160 r.p.m.) and the depth of cut was (1mm). Figure **(3)** shows the specimens after machining operation. The first three sets of experiments were repeated but with the use of cutting fluid. It is also repeated on a computerized numerically controlled machine tool CNC (Siemens - EMCO Turn 342) turning machine, shown in figure **(4)**, with the same cutting parameters with the use of cutting fluid. Other parameters such as tool nose radius, workpiece material, workpiece diameter, workpiece length was taken as constant.

RESULT AND DISCUSSION:

Surface roughness was measured for the turned component at different cutting parameters by changing one parameter and fixing the others to determine the effect of each parameter on the surface roughness. Turing operation was carried out on two deferent machine tools to determine whether the type machine itself affects the surface roughness.

The results of the surface roughness are shown in figures **(5)**, through **(7)** respectively. Figure **(5)** represents the relation between the surface roughness and cutting speed, where all other parameters were remained constant in order to get only the effect of cutting speed on the surface roughness. It is clear that surface roughness decreased by increasing cutting speed in all of the three cases in using the conventional machine with and without cutting fluid and in using the CNC machine. This attributed is due to the decrease in the built up edge size at higher speed according to (D. Philip Selvaraj and Palanisamy Chandramohan, 2010), where the influence of the built up edge became negligible. In addition, the cutting process becomes more and more stable as the speed increases, and the vibration during cutting at the highest speed is lower which concede with **(**A.K Ghani et al., 2002).

Figure **(6)** represents the relation between the surface roughness and depth of cut where the machining was carried out on the conventional machine tool with and without cutting fluid and on the CNC with cutting fluid. Cutting speed and feed and all of the other parameters were remained constant. It is clear that surface roughness is increased by increasing depth of cut for all of the three cases. It is due to the increase in machine tool vibration which increases due to the increase in the cutting force according to (Helmi A. and Hassan, 2008), which increases by increasing the depth of cut, and also due built up edge formation according to (Thomas Childs et al, 200) .

Figure **(7)** represents the relation between the surface roughness and feed, where all other parameters were remained constant. It is clear that surface roughness is decreased by increasing the feed in all of the three cases in using the conventional with and without cutting fluid and in using the CNC machines. It concedes with the theoretical relation between the ideal surface roughness and feed (J. Paulo et al., 2011**)**.

To improve machining productivity by increasing feed and depth of cut will be against achieving better surface quality. However it is obviously that increasing the feed significantly influences the surface roughness than increasing the depth of cut. Thus, is it recommended to increase the depth of cut more than feed to improve the machining productivity.

Figures **(5)**, through **(7)** show that in case of using cutting fluid, surface roughness decreased in all cases, than without using cutting fluid. This attributed is due to the reduction in the tool temperature which reduces the formation of built-up edge and the coefficient of friction. And fluid penetration into the cutting interface reduces adhesion between the tool face and the chip which reduces the size of the built up edge (Vishal S. et al., 2008).

These figures also show that turning the specimens on the CNC machine gave better results where the surface roughness decreased than on the conventional machine tool. It is related to the stiffness and dynamic characteristics of the machine-tool structure.

CONCLUSIONS:

In this work, steel specimens were machined out on CNC and conventional turning machines at different cutting parameters. Surface roughness was measured for all of the machined specimens.

The conclusions drawn from the present research are summarized as follows:
1. By increasing spindle speed, surface roughness decreased.
2. As the depth of cut increased, the Surface roughness increased.
3. Surface roughness increased by increasing too feed.
4. By using cutting fluid, surface roughness decreased.
5. The feed had highest effect on surface roughness than depth of cut.
6. Machined surface roughness is less on the CNC turning machine than on the conventional machine.

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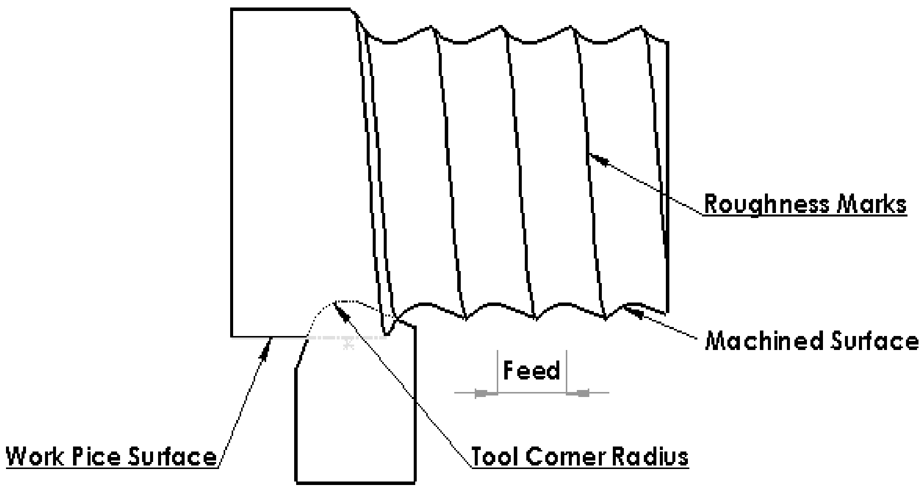

Figure (1) Ideal surface roughness due to tool feed

Figure (2) sample pf machined specimens

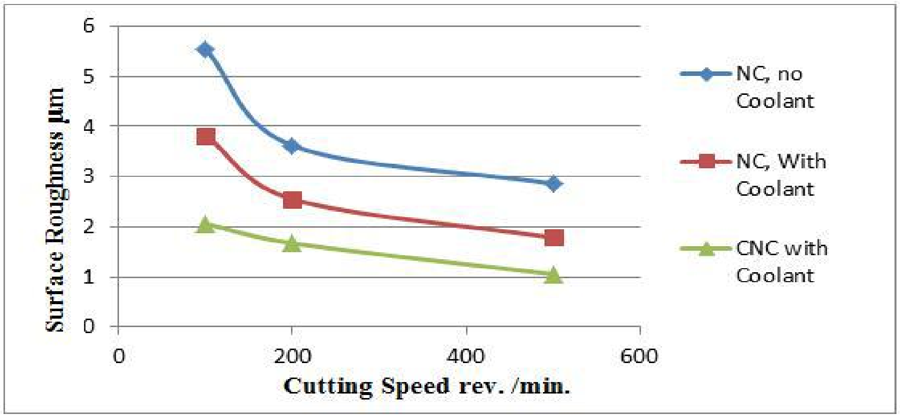

Figure (5) Relation between cutting speed and surface roughness, Depth of cut was fixed on 1 mm feed on 0.064 mm/rev.

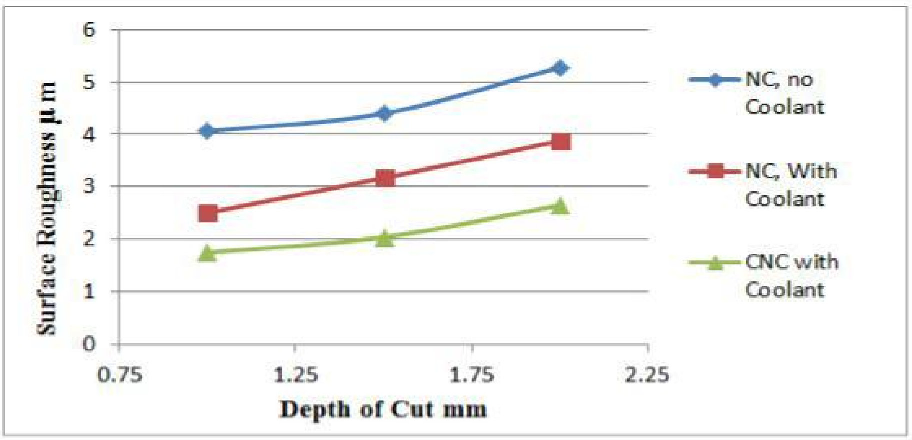

Figure (6) Relation between depth of cut and surface roughness, cutting speed was fixed on 160 rev. /min. and feed 0.05 mm/rev.

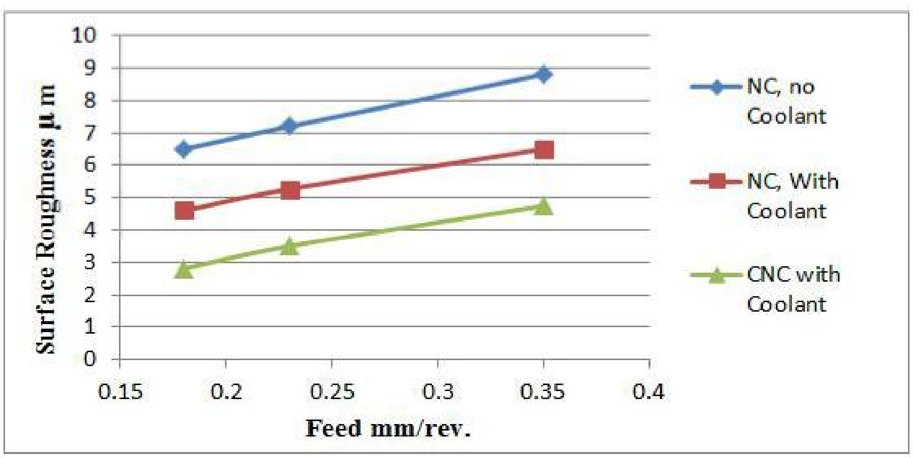

Figure (7) Relation between feed and surface roughness, cutting speed was fixed on 250 rev. /min. and depth of cut 1 mm