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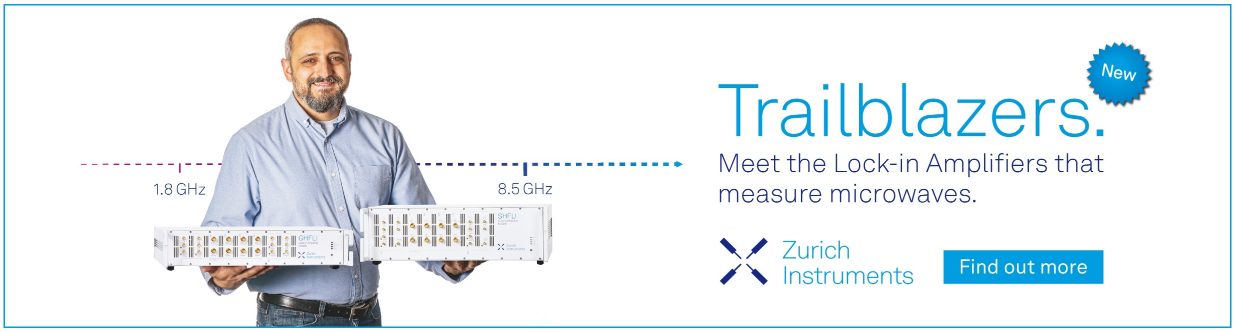

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Analysis of the Effect of High Carbon Steel Softening Process on the Quality of Lathe Machining Results

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Abstract. In this paper, we studied lathe machining characteristics of hard materials that have been softening with an annealing process. We utilized carbide cutting tools with variations of machining parameters and machining perform without cooling water. The data was obtained experimentally by giving machining variables of spindle speed of 750 rpm, 1000 rpm and 1250 rpm; feed (f) of 0.035 mm/rev, 0.05 mm/rev, 0.085 mm/rev and 0.18 mm/rev; and cutting depth of 0.5 mm. The materials used were high hardenability antifriction bearing steel ASTM A 485 and annealing process was carried out at a temperature of 1000 °C. After the machining process, surface roughness (Ra) measurement was performed using Mitutoyo Surface Tester 301. Measurements were performed on both materials which were annealed and without annealing as a reference. The results show that annealing treatment increased the surface roughness. The Ra value for material without annealing was 1.150 μm to 2.865 μm and annealed material of 1.394 μm to 6.999 μm. Maximum roughness occurred in spindle speed of 1000 rpm for material without annealing, while annealed material it happened at 750 rpm. On the other hand, minimum roughness occurred in spindle speed of the 750 rpm for material without annealing, while annealed material happened at 1250 rpm. In conclusion, this indicated that the softer material due to annealing treatment will largely depend on spindle speed choice on produced high quality (low surface roughness) in machining process especially on dry machining.

INTRODUCTION

The current machining trend consists of two types: high-speed machining and hard machining. Hard material on lathe machining has many problems, such as cutting tools wearing out too quickly so that production costs become higher. High-speed machining is triggered by increased demand on high productivity with low production costs as this type of machining can accommodate high cutting and material release volume from the parent material will increase. Significant machining time savings will be obtained. In addition, high-speed machining can produce refined products and more precise sizes. Hard machining is carried out on work objects that have a hardness greater than 40 HRC. The hard fraise process can be performed on various types of metals such as alloy steel, steel for bearings, work tools for hot and cold steel, high-speed steel, and hardened cast steel. To support the latest machining, the cut cutting tool used must be reliable and have capable material properties, which wear resistance and high temperature. One of the developments of cutting tools is the use of harder materials. Hard material cutting tools are cutting tools that can minimize downtime as this type of cutting tool is easily replaced when worn out [1,2]. The use of hard metal cutting tools has resulted in maximum productivity so that it will increase the replacement time of cutting tools, products precision, reduce production time and production costs so that the selling price of the product will be affordable and will ultimately strengthen the company's ability to compete with its competitors.

Some researchers have conducted studies on the use of insert cutting tools in the machining process, especially for hard machining. Various methods have been used in the machining process to determine cutting parameters, cutting tool type, measured quantity and analysis method [3]. All methods used lead to machining process optimization, namely obtaining low cutting force and small surface roughness. In addition, the development of the metal cutting

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process with machine tools is also directed at cutting tools endurance, low production cost and product accuracy. One solution is the use of carbide insert cutting tools.

The difference of dry machining and wet machining has been investigated widely [4, 5]. Venkatesan conducted a study on the effect of Ni-Cr cutting parameters, Inconel 625 alloys, using coated carbide insert tools (AlTiN PVD) and using a dry machining process, the measurements of cutting force and surface roughness were analyzed with signal-to-noise comparison analysis (S/N), variance analysis (ANOVA), and regression analysis. It obtained a lower cutting force and good surface quality in dry cutting conditions [6]. Wet machining is machining that is in the process done with a coolant. The main function of the coolant is to reduce the cutting temperature by reducing the force of friction, as a medium heat carrier of the cutting area and serves as a grunt carrier. When the cutting temperature decreases, the lifespan of the cutting tool will increase. This process will be different from the dry machining process wherein in the dry machining process there is found a large friction force so that the cutting temperature is expected to be very high. This high cutting temperature will reach the melting point of the cutting tool material and can change the microstructure of the cutting tool tip [7]. The tip of the cutting tool becomes soft and undergoes pressure to decrease the strength of the cutting tool. It ultimately will influence machining products.

Based on the above description, a more in-depth study of the use of an insert cutting tool is required in the dry machining process of hard materials under the conditions of cutting parameters. In this study, we proposed an overview of the quality of annealed material processed with lathe machining and their relationship to the surface roughness of dry machining on hard materials.

MACHINING THEORY

Material cutters with machine tools are industrial activities that aim to form machine components or other equipment. Basic developments of cutting tools and machine tools facilitate human work and produce products quickly, effectively, and economically. The quality of machining products is also affected by cutting parameters and cutting temperature. Cutting parameters, namely: cutting speed (*Vc*), depth of cut (*a*) and feed (*f*). In the machining process, it is important to know the value: cutting force (*F*), cutting temperature (*Tp*), level of formation of chips (*Z*) and cutting time (*t*).

Cutting speed holds a major role in the quality of machining products where the determination of speed value is very important to know. The cutting speed is directly proportional to the rotation of the workpieces. The relationship of cut speed with rotation is indicated by the following equation [8]:

$$V_c = \frac{\pi . d . n}{1000} \text{ [m/min]} \tag{1}$$

The following equations are used to determine the characteristics of machining, namely:

- Feed speed,

$$V_f = f . n \text{ [mm/min]} \tag{2}$$

- Cutting time,

$$T_c = \frac{l_t}{v_f} \text{ [mm/min]} \tag{3}$$

- The speed of chips formation,

$$Z = A . V_c \text{ [mm}^3\text{/min]} \tag{4}$$

RESEARCH METHODS

In this study, we used ASTM 485 working material with a diameter of 50 mm, length of 350 mm with a hardness value of 62 HRC. The cutting tools uses were carbide insert cutting tools. The machining process used was turning without cooling water. Machining variables selected were spindle speed (750 rpm, 1000 rpm and 1250 rpm); cutting depth (0.5 mm); and feed (0.035 mm/rev, 0.05 mm/rev, 0.085 mm/rev and 0.018 mm/rev). The annealing temperature was 1000 °C. Surface roughness (Ra) measurement was performed using Mitutoyo Surface Tester 301.

Figure 1 shows carbide insert cutting tools and its holder used in this study. The insert geometry identity follows the American National Standard Institute (ANSI) and DNMG-432, as follows:

D: Insert shape of 55° diamond.
N: Relief angle of 0°.
M: Tolerance of the inscribed circle and thickness of ± 0.002 and ± 0.005 respectively.
G: Insert with a hole and chip breaker on both faces.
4: Inscribed circle of 1/2 inch.
3: Thickness of the insert of 3/16 inch.
2: Nose radius of 1/32 inch.

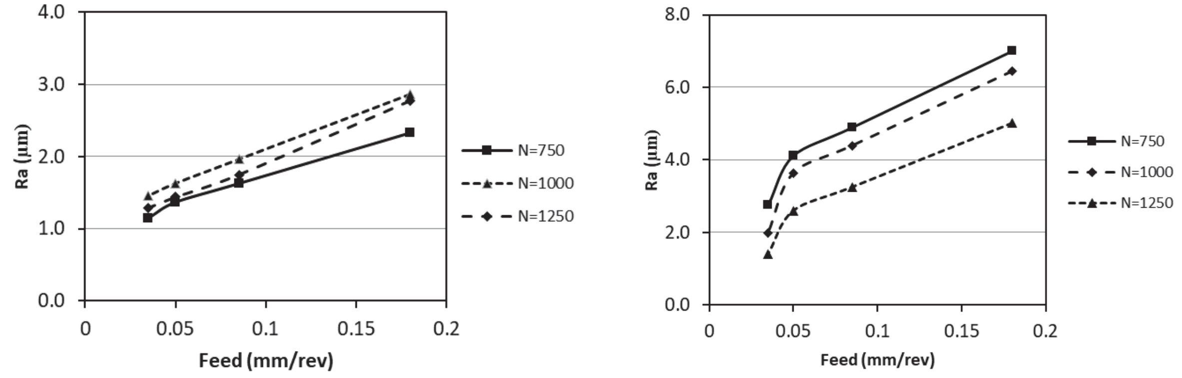
(a) **(b)**

FIGURE 1. Cutting tools used in the study, (a) Carbide insert cutting tool, (b) Cutting tool handle

The machining process was done into two materials which without annealing and that undergo an annealing process. Furthermore, surface roughness (Ra) measurements were taken against both materials. The results of roughness measurements were then compared and further investigated the relationship of surface roughness with spindle speed and feed.

RESULTS

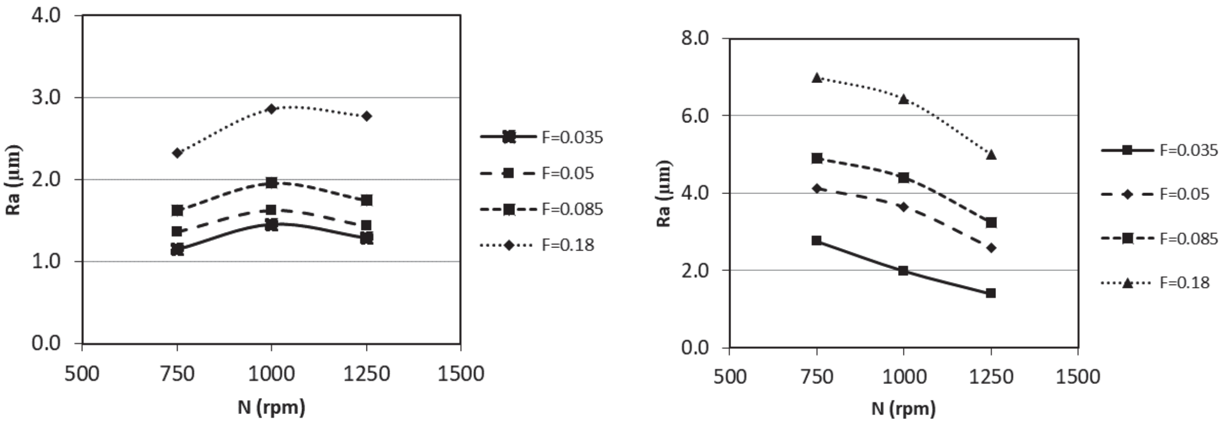
The relationship between feed and surface roughness was shown in Fig. 2. Fig. 2(a) and Fig. 2(b) show the comparison of material without annealing treatment and with annealing treatment at 1000^{o}C. The spindle speed and feed rate have a small impact on workpieces' surface changes on the material without annealing treatment. The increased feed rate and spindle speed correlated increase of surface roughness. The Ra value for material without annealing was obtained between 1.150 µm to 2.865 µm. On the other hand, Spindle speed and feed parameters gave more impacts related to surface roughness for annealed materials. The increased feed rate correlated increase of surface roughness, however, the spindle speed works opposite ways. The higher spindle speed made lower surface roughness. The value of Ra for annealed material has large value between 1.394 µm to 6.999 µm.



(a) (b)

FIGURE 2. The relationship between feed and surface roughness and spindle speed, (a) Feed vs Ra (without Annealing), (b) Feed vs Ra (Annealed at 1000°C)

The relationship between spindle speed rotation and surface roughness was shown in Fig 3. Fig. 3(a) and Fig. 3(b) show the comparison of material without annealing treatment and with annealing treatment at 1000 °C. Fig. 3(a) shows that the highest Ra value on the material without Annealing treatment was at 1000 rpm. On the other hand, the annealed materials have lower Ra when the spindle speed increased. The higher the feed parameters made the Ra value increased. Largest Ra value at feed 0.18 mm/rev for both types of materials. This indicated that the softer material due to annealing treatment will largely depend on spindle speed choice on produced high quality (low surface roughness) in machining process especially on dry machining [9].



(a) (b)

FIGURE 3. The relationship between spindle speed and surface roughness, (a) N vs Ra (without Annealing), (b) N vs Ra (Annealed at 1000°C)

CONCLUSION

In conclusion, we found that annealing treatment had an impact on changes in the value of surface roughness (Ra). The Ra value increased due to the material turn into softer material via annealing treatment. The Ra value for materials without annealing was between 1.150 μm to 2.865 μm and annealed materials range of 1.394 μm to 6.999 μm. The spindle speed and feed rate have a small impact on workpieces' surface changes on the material without annealing treatment. In contrast, Spindle speed and feed parameters gave more impacts related to surface roughness for annealed materials. The increased feed rate correlated increase of surface roughness, however, the spindle speed works opposite ways. Maximum roughness occurred in spindle speed of 1000 rpm for material without annealing, while annealed material happened at 750 rpm. On the other hand, minimum roughness occurred in spindle speed of the 750 rpm for material without annealing, while annealed material happened at 1250 rpm. This indicated that the softer material due to annealing treatment will largely depend on spindle speed choice on produced high quality (low surface roughness) in machining process especially on dry machining.

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