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The study of high speed fine turning of austenitic stainless steel

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ABSTRACT

Purpose: The purpose of this research paper is focused on the surface roughness variation in high speed fine turning of the austenitic stainless steel.
Design/methodology/approach: A series of experimental tests have been done to evaluate the possibility of high speed fine turning of the austenitic stainless steel from the surface roughness variation and machining stability.
Findings: It was found that, the smaller the feed rate, the smaller the surface roughness value. But when the feed rate smaller than the critical feed rate, the chatter will occurs and the surface roughness of the work piece would be deteriorated.
The higher the cutting speed is, the higher the cutting temperature of cutting tool is. The cutting tool will be soften and the surface roughness of the workpiece will be deteriorated.
Research limitations/implications: The tool chattering would caused poor surface roughness in high speed fine turning for feed rate smaller than 0.02 mm/rev. The chatter suppression method must be considered when high speed fine turning of austenitic stainless steel.
Originality/value: Most of the stainless steel machining proceeds at low cutting speed because the austenitic stainless steel is a hard machining material. The research result of this paper indicated that high speed fine turning of austenitic stainless steel is possible.
Keywords: High speed fine turning; Austenitic stainless steel; Surface roughness; Chatter; Critical feed rate

1. Introduction

Austenitic stainless steel has the excellent property of corrosion resistant, formability and strength. It's widely used in food and chemical industry, and also mold industry. However, stainless steel has common weakness of hard machining for the work hardening of the material during machining operation [1-3].

The challenge of modern machining industries is mainly focused on the achievement of high quality in terms of workpiece dimension accuracy, surface integrity, and high production rate [4-6]. Surface roughness plays an important role in the evaluation of machining accuracy and machinability [7-9].

The average surface roughness is given by [7-9]:

$$R_a = \frac{1}{L}\int_0^l |y(x)|dx \tag{1}$$

Where Ra is the arithmetic average deviation from the mean line. L is the sampling length, y coordinate of the profile curve.

Numerous investigators have been conducted to determine the effect of parameters such as feed rate, tool nose radius, cutting speed and depth of cut of surface roughness [10-16].

With an environment of fierce competition as well as the production cost keeps rising. Besides heading towards to automatic, energy-saving and unmanned, in order to increase production efficiency and shorten machining times, high speed machining consequently becomes one of the main methods. Since the successful developed of high speed spindle and progressive material techniques, high speed machining (HSM) has become a common trend supplied in manufacturing industry [10-12].

Most of the stainless steel machining proceeds at lower cutting speed [1], it is rarely discussed about the high speed machining behavior of the stainless steel. This study is pointing to the high speed fine turning of the austenitic stainless steel. From the surface roughness variation to understand the machinability of the austenitic stainless steel.

2. Experiment planning

In order to understand the variation condition of the surface integrity, experiment of cermet turning tool against austenitic stainless steel dry cutting test was conducted. The cutting test used disposable cermet turning tool on CNC lathe to perform turning experiment. The experimental set-up is shown in Fig. 1. The turning workpiece is chucked on CNC lathe by three jaw chuck, and supported at tail by life center. The specification of tool holder was MTJNR2020K16, and the specification of cermet cutting tool was TNMG160408R, the nose radius of the cutting tool is 0.8 mm. The workpiece materials are austenitic stainless steel SUS303, SUS303Cu and SUS304. The cutting speed are 250, 350 and 450 m/min. the feed rate are 0.04, 0.06, 0.08 and 0.10 mm/rev, the depth of cut is fixed at 0.1 mm.

After machining, the surface roughness measurement as shown in Fig.2, is used to measure the surface roughness of the workpiece. Every surface roughness value had been tested 5 times and calculate it's average.

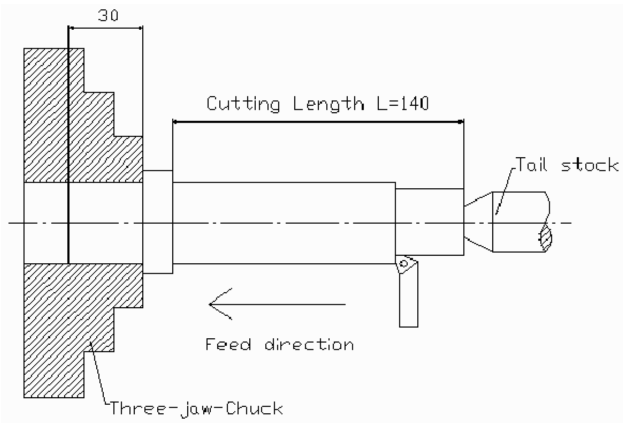

Fig. 1. Experimental set-up

3. Experimental result and discussion

First of all, performing high speed fine turning of stainless steel SUS304, the result was shown in Fig.3. The cutting speed doesn't make big difference to surface roughness when the feed rate is smaller than 0.05 mm/rev. But when the feed rate is greater than 0.08 mm/rev, as shown in Fig.3, we can see that surface roughness value reach the best level when the cutting speed V = 350 m/ min. And the surface roughness value are all greater than 1.2 µm when the cutting speed V = 250 and 450 m / min.

Fig. 2. Surface roughness measurement

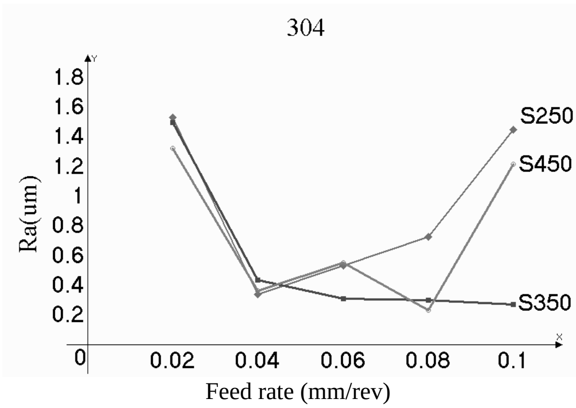

Fig. 3. Surface roughness variation for SUS304

The surface roughness value reaches the best level when the feed rate are between 0.04 and 0.08 mm / rev. According to the definition of surface roughness value[1]:

$$R_a \propto \frac{f^2}{r} \tag{2}$$

Surface roughness value Ra is negative proportion with the nose radius r of the cutting tool. In other words, the surface roughness value decrease with the increasing of nose radius. Large nose radius tools have produced better surface roughness than small nose radius tools. But chatter phenomena will occurs when the nose radius is too large [15,16]. So, in this study, the nose radius of the cutting tool is fixed at 0.8 mm. as in example 2, we also found that the surface roughness is positive proportion with the feed rate f. In other words, the smaller the feed rate is, the smaller the surface roughness value is. If we want to reach the best surface roughness level, we must minimize the feed rate first.

However, from Fig.3, we found that the surface roughness value was deteriorated when the feed rate f = 0.02 mm/rev. Through observation, we found out that it was the chatter phenomena through the turning process. Chatter phenomena may cause the deterioration of the surface roughness. From Fig. 4, we can see the chatter mark on the workpiece surface clearly.

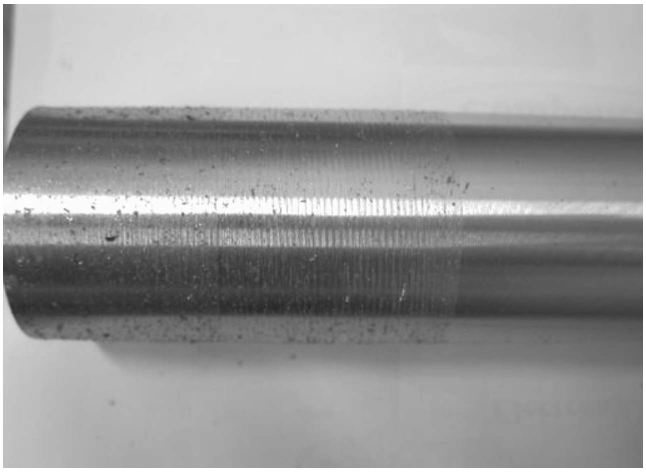

Fig. 4. Chatter occurred for f=0.02 mm/rev

In this condition, the chip shape is as shown in Fig.5. Although the vibration of the chatter phenomenon caused the chip shape changed from continuous type to discontinuous type, but the surface roughness value will be deteriorated by the chatter mark on the turning surface.

Fig. 5. Discontinuous chip for chatter occurred

When fine turning with ideal cutting condition, the chip shape is as shown in fig. 6. It is indicated that the chip is continuous with fine chip breaking.

Because of the limitation of machine structure, the chatter phenomena occurs as feed rate being smaller than critical feed rate. In order to get the best surface roughness, unlimited minimizing the feed rate doesn’t worked, we must try to increased the dynamic rigidity of the machine structure.

When turning stainless steel SUS303, the surface roughness variation is shown in Fig.7. The variation trend is similar to the turning of stainless steel SUS304.Under the cutting condition of cutting speed V = 250 to 350 m/ min and the feed rate f = 0.04 to 0.06 mm/rev, it can reach the fine surface roughness value. Therefore, we can said that the ideal cutting condition of high speed fine turning of stainless steel of SUS303 is cutting speed V = 250 to 350 m/ min and the feed rate f = 0.04 to 0.06 mm/rev. In this condition, the workpiece’s surface is shown in Fig. 8.

Fig. 6. Continuous chip shape with fine chip breaking

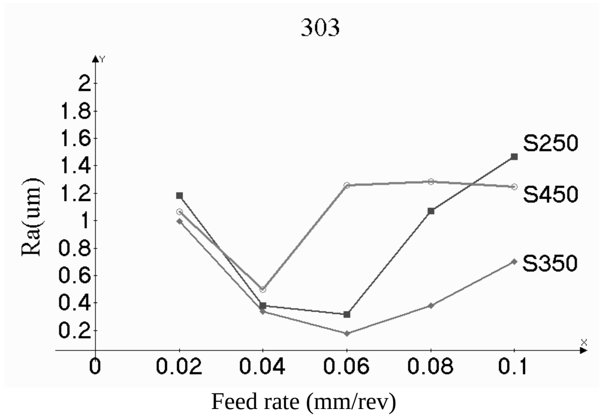

Fig. 7. Surface roughness variation for SUS303

Fig. 8. Fine surface for ideal cutting condition

SUS303Cu is the material which increased the Cu content of SUS303, in order to increased the strength of the stainless steel SUS303. When high speed fine turning of SUS303Cu, the surface roughness variation is shown in Fig.9. From Fig.9, we can seen that the surface roughness value get worse when the cutting speed V being changed from 250 to 450 m/min. It's because the higher the cutting speed is, the higher the cutting temperature is, which cause the soften of the cutting tool and worsen the cutting surface. When the feed rate f = 0.04 to 0.06 mm/rev, the surface roughness value is very small no matter the cutting speed is high or low. The chatter phenomena occurs when the feed rate f = 0.02 mm/rev.

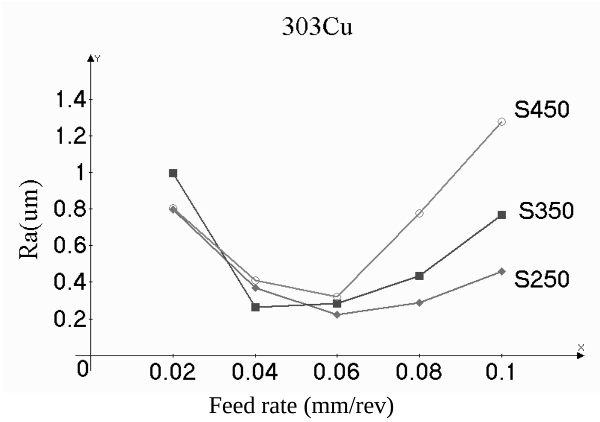

Fig. 9. Surface roughness variation for SUS303Cu

4. Conclusions

Following conclusions are obtained from analysis the above stated experimental results

- When performing fine turning of austenitic stainless steel, the smaller the feed rate, the smaller the surface roughness value. But when the feed rate is smaller than critical feed rate, the chatter phenomena will occurs and the surface roughness of the workpiece will be deteriorated.
- The higher the cutting speed is, the higher the cutting temperature of the cutting tool. This phenomena will be caused the soften of the cutting tool and deteriorated the surface roughness of the workpiece.
- The ideal feed rate for high speed fine turning of austenitic stainless steel is 0.04 to 0.06 mm/rev.
- The critical feed rate for chatter is 0.02 mm/rev in high speed fine turning of austenitic stainless steel.

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