Experimental Investigations and Numerical Simulations of the Relationship between Tool Geometry and Cutting Chatter

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Keywords: Cutting chatter, tool geometry, Numerical simulation

Abstract. This paper is armed at researching the suppression method of cutting chatter. The occurrence of chatter is strongly influenced by the tool geometry. In this paper, The numerical simulation results are in good agreement with the Experimental investigation results. The results show. Tool geometry is the first essential factor of the occurrence of cutting chatter. A large rake angle and a small clearance angle lead to a high cutting stability. A decrease in rake angle and an increase in clearance angle will greatly increase the degree of the cutting chatter and decrease the cutting stability.

1. Introduction

Cutting chatter is present in almost all the cutting process. It is the main obstacle to the increase of productivity. Therefore, the research on its control methods is very meaningful for improving the processing ability of machine tools and machining accuracy and prolonging the service life of cutting tool. This paper Discusses the relationship between tool geometry and cutting chatter by experimental investigations and numerical simulations[1].

2. Experimental Investigations

2.1 Experimental setup

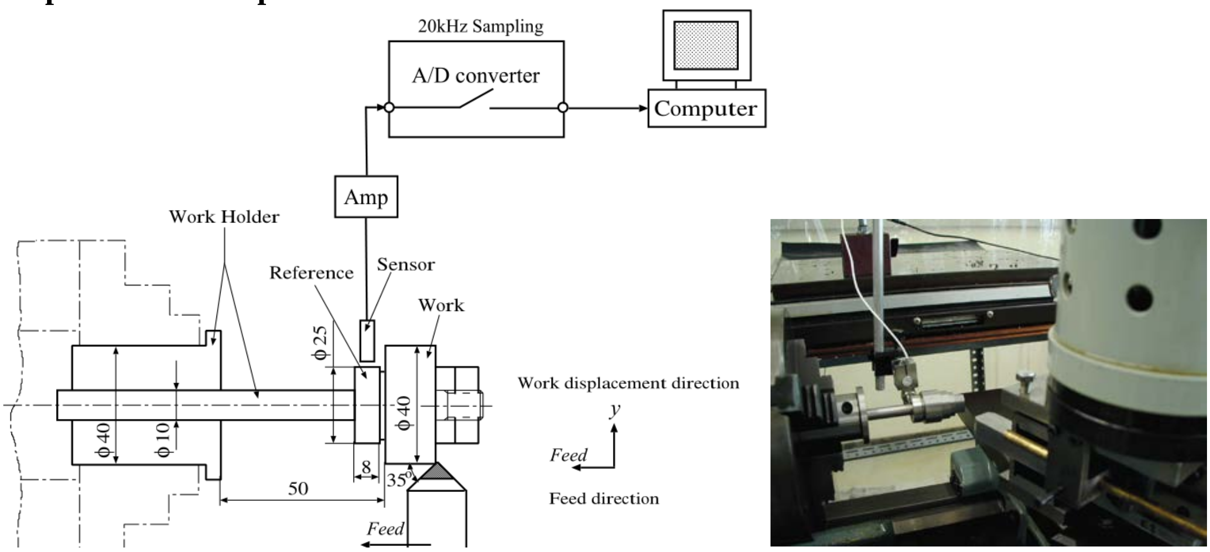

Fig. 1 The cutting setup

The cutting setup in the experiment is shown in Fig. 1. This setup consists of a tool and a rotary workpiece. A slender holder support the workpiece. The diameter of the workpiece is 40 mm. The material of the workpiece is S45C carbon steel. The material of the tool is carbide MF10.

In order to measure the work displacement in the y direction in Fig. 1, we set an An eddy current sensor in the cutting setup. The frequency response of the ranges from 100-80,000HZ. An A/D converter converts the analog signals produced by the sensor to the digital signals at a sampling frequency of 20 kHz and stored in the PC at last[2].

In the experiment, the LMS.Testlab data acquisition analysis system which is produced by Belgium's LMS Corporation is used to gathering and analyze data, including a data acquisition box and a section data acquisition analysis software Testlab 9A[3].

2.2 cutting conditions

We use four different tool geometries to observe the degree of the cutting chatter.The spindle speed is set to be 4600 r/min and the cutting speed is set to be 58 m/min. The cutting conditions of this experiment are shown in Table. 1.

Table. 1 Experimental cutting conditions

Cutting conditions	Spindle speed Cutting speed Depth of cut Feed rate	460r/min 58m/min 0.05mm 0.051mm/rev
Tool edge	Rake angle α_0 and Clearance angle γ_0	case(1): α_0=9°，γ_0=1° case(2): α_0=6°，γ_0=4° case(3): α_0=3°，γ_0=7° case(4): α_0=0°，γ_0=10°
	Material Corner radius Side cutting angle	MF10 0.05 mm 35°
Workpiece	Material Diameter	S45C 40 mm

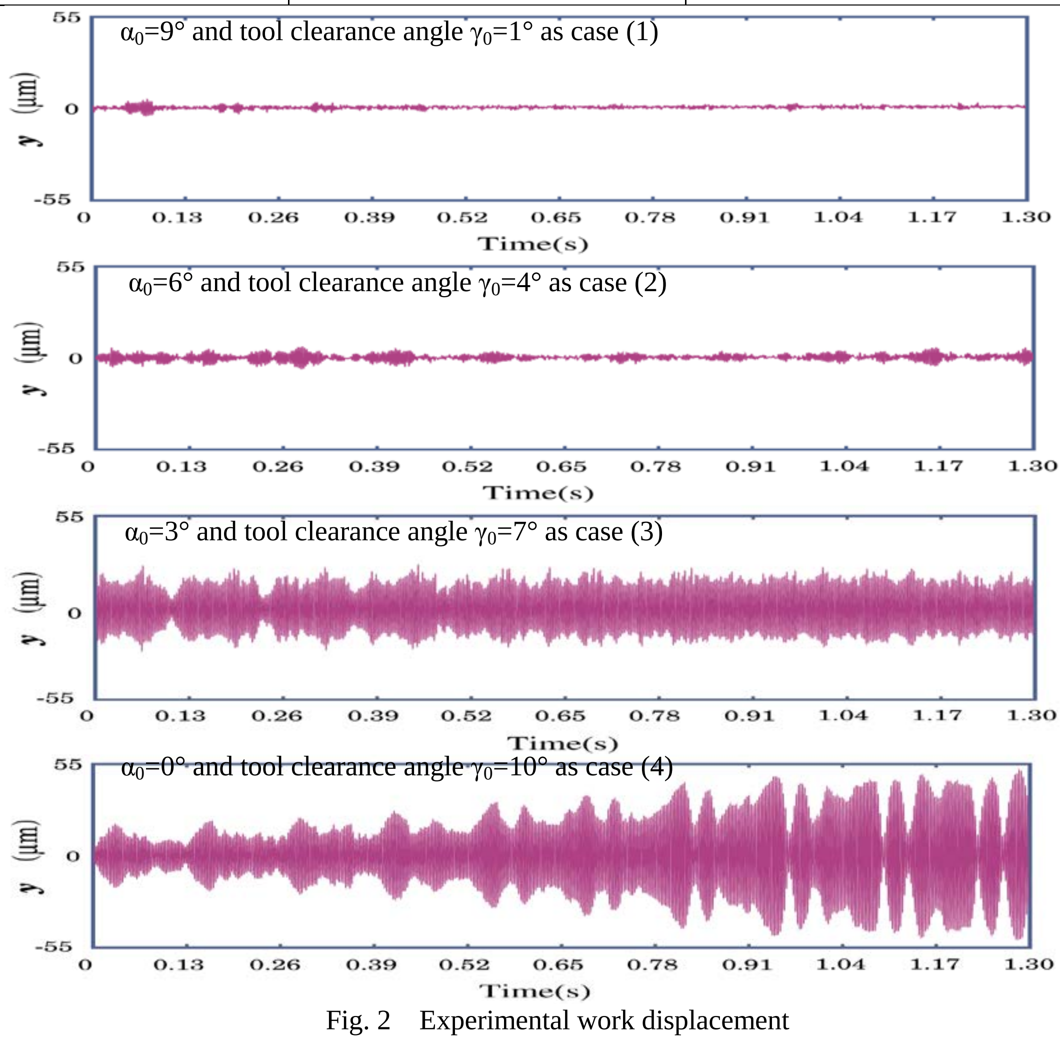

Fig. 2 Experimental work displacement

2.3 Experimental results

The experimental results of the relationship between four different tool geometries and cutting chatter during ten revolutions of the workpiece are shown in Fig. 2.

In case (1), the maximum amplitude value of the work displacement is 10μm. In case (2), the maximum work displacement amplitude value is 14μm. In addition, The cutting states of case (1) and case (2) keep stable. The results of case (1) and case (2) show that a large rake angle and a small clearance angle lead to a high cutting stability[4].

In case (3), the maximum work displacement amplitude value is 55μm. In case (4), the maximum work displacement amplitude value is 102μm. Besides, the chatter sound of case (3) and case (4) are audible. The results of case (3) and case (4) show that a decrease in rake angle and an increase in clearance angle will greatly increase the degree of the cutting chatter and decrease the cutting stability.. Tool geometry is the first essential factor of the occurrence of cutting chatter[5].

3. Numerical simulation

3.1 Numerical simulated conditions

We use the cutting model proposed by Tarng, the model is a regenerative chatter cutting model which can describe the dynamics of the processing behavior, reflect the main parameters of regenerative chatter and obey the basic law of the regenerative chatter.Then we use the fourth Runge–Kutta–Gill numerical integration to calculate the model in MATLAB.

First we need obtain the simulated system parameters, including the simulated cutting parameters and simulated hardware parameters. In order to compare the simulated results with the experimental results, both of the simulated cutting parameters and simulated hardware parameters must be obtained through the experiments[6].

The simulated cutting conditions including four different tool geometries are as the same as the experimental cutting conditions. The simulated hardware parameters are determined on the basis of the measured hardware parameters. We get simulated hardware parameters by modal test of hammering method. m = 0.19 kg, c_1 = 52 Ns/m, c_2 = 63 Ns/m, k_1 = 0.70 MN/m, k_2 = 1.12 MN/m.

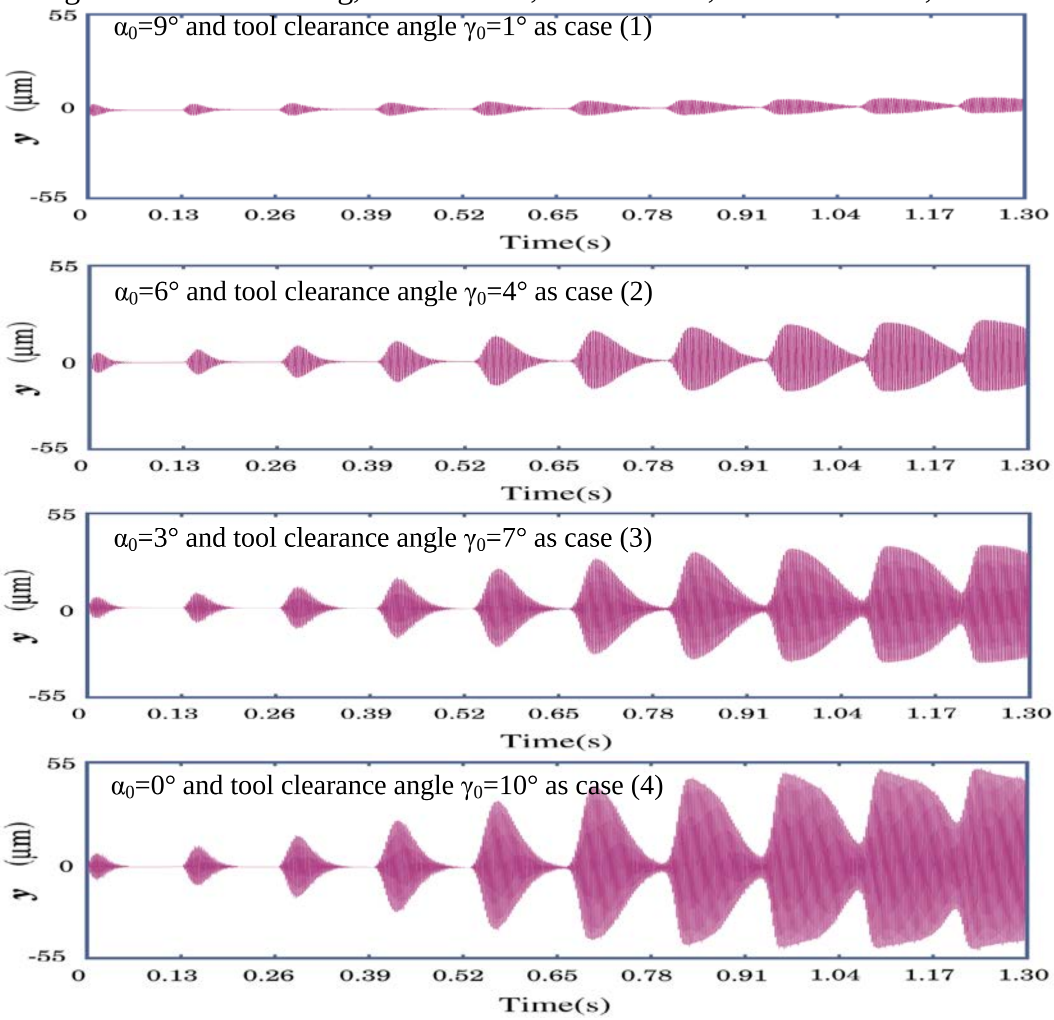

Fig. 3 Simulated work displacement

3.2 Simulated results

The simulated results of the relationship between four different tool geometries and cutting chatter during ten revolutions of the workpiece are shown in Fig. 3.

The work displacements of case (1), case (2), case (3) and case (4) are 10 μm, 40 μm, 70 μm amd 100 μm respectively. With the number of revolutions increased, The work displacements of case (1), case (2), case (3) and case (4) increase until the finite amplitude value. Unstable cutting chatter occurs in the finite amplitude. Besides, a decrease in rake angle and an increase in clearance angle will incease the finite value. The simulated results show that a decrease in rake angle and an increase in clearance angle will greatly increase the degree of the cutting chatter and decrease the cutting stability. Tool geometry is the first essential factor of the occurrence of cutting chatter[7].

3.3. Comparison of simulated results and experimental results

The amplitude of the experimental and simulated work displacement versus the tool geometry is shown in Fig. 4. The comparison of the amplitude shows that simulations closely match the experimental displacements, but there still exists some errors between experimental results and simulated results. The reason may be the regenerative chatter effect. Which is caused by the overlapping property between the current cut and the previous cut in cutting process[8].

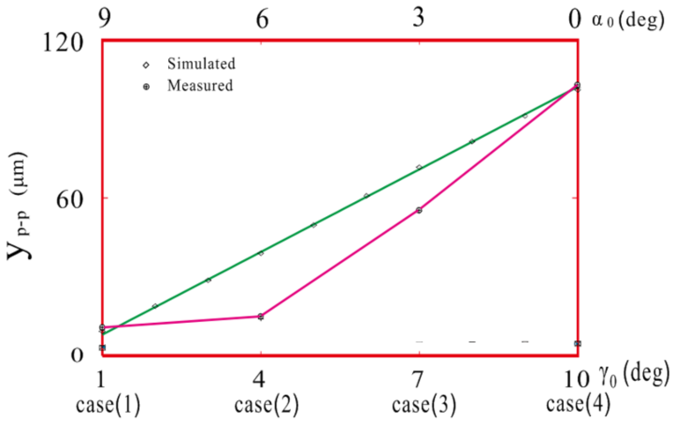

Fig. 4 Experimental and simulation results for the effect of the tool geometry on the displacement

At last, the frequency components of the experimental and simulated work displacements in case (1) and case (4) are compared. Fig. 5 shows the power spectra of the experimental results and simulated results[9]. The comparison of the experimental results and simulated results indicate that the simulated results are in good agreement with the experimental results in the frequencies of the main vibrations[10].

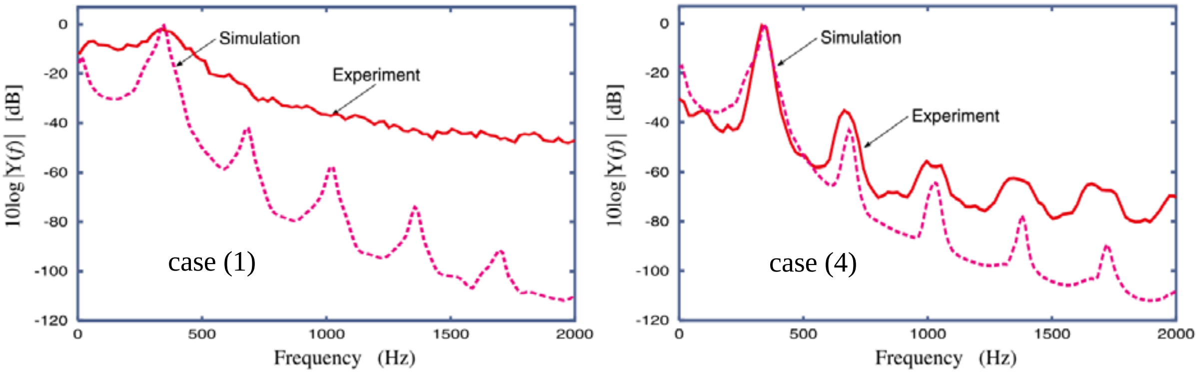

Fig. 5 Power spectra of the experimental and simulated work displacement in case (1) and case (4)

4. Conclusion

The simulated results are in good agreement with the experimental results. Tool geometry is the first essential factor of the occurrence of cutting chatter. It means the occurrence of chatter is strongly influenced by the tool geometry. A large rake angle and a small clearance angle lead to a high cutting stability. A decrease in rake angle and an increase in clearance angle will greatly increase the degree of the cutting chatter and decrease the cutting stability.

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