Effect of Applied Voltage on Tool Wear in Cutting Nickel-base Superalloy

Hui Wang[1, 2,a], Fusheng Ni[1,2,b], Jingjing Liu[1], Runze Yu[1]

[1] College of Mechanical and Electrical Engineering, Hohai University, Changzhou, CHN

[2] Engineering Research Center of Dredging Technology of Ministry of Education，

Hohai University, Changzhou, CHN

[a]whui1268@aliyun.com, [b]fushengni@163.com

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Abstract. The machinability of Nickel-based superalloy GH4169 is poor, in order to improve machining efficiency, reduce costs, it is necessary to study the various factors that affect the tool wear. In this paper.The tool wear tests were carried out to investigate the effect of an externally applied voltage on insert flank wear in turning of Ni-based superalloy GH4169 with coated carbide tool YBG202. Flank wear morphology was observed and the VB values were measured. The result showed that the applied voltage affected the tool wear obviously, When the insert was no externally voltage applied, the flank wear was least, when the insert was cathode, the flank wear was lower than when the insert was anode. The insert wear increased as applied voltage increased. The externally applied voltage accelerated the tool wear due to serious adhesive and abrasive wear, which leaded to the cutting efficiency decreased and cost increased, so it should try to avoid applied voltage when machining nickel-based superalloy.

Introduction

Nickel-based superalloy GH4169 is widely employed in the aerospace industry, in particular in the hot sections of gas turbine engines, due to their high-temperature strength and high corrosion resistance. As a kind of difficult-to-cut materials, the machinability of nickel-based superaloy are poor, especially the high cutting force and cutting temperature, short tool life and poor quality of the machined surface[1].In order to improve machining efficiency and reduce costs, it is necessary to study the factors that affect tool wear.

As we all know, the additional current and voltage will be produced in cutting process, which affect the cutting process. A. Gangopadhyay [2-3]and Yamamoto[4] investigated the friction and wear behavior of a steel pair and milling process when an electric current was passed through the contact. It observed that friction and wear behavior of two components sliding against each other can be greatly influenced by an externally applied electrostatic field or electric current.Tool wear were reduced through an externally applied electric current in milling process with uncoated carbide milling inserts to machine AISI 4140 pre-heat treated steel.

The objectives of this study were to investigate whether it can reduce the wear through an externally applied voltage in machining process. Therefore, in this paper, the effect of externally applied voltage on tool wear in cutting nickel-base superalloy was studied.The tool wear tests will be carry out.

Cutting test

Machine, Tool and Materials. The experiment was set up on a universal turning machine CA6140 with a vertical milling head, powered by a 7.5Kw electric motor giving a speed range of 10～1400rev/min and a feed range of 0.014～3.16mm/rev.

The inserts is coated carbide tool YBG202 with MT-TiCN, $A1_2O_3$ and TiN coated. The geometric parameters of tool are shown in Table 1.

Table 1 Tool geometry parameterss

γ_o	α_o	κ_r	κ_r'	λ_s	α_o'	r_ε
14°	6°	75°	15°	-6°	6°	0.5mm

Ni-based superalloy GH4169 is selected as workpiece material in the experiments. Cutting test was performed on precipitation with a bar. Chemical composition of the material is given in Table 2 and the physical and mechanical properties of GH4169 are shown in Table 3, respectively.

Table 2 Chemical components of the materials used（W_t）%

Ni	Cr	Nb	Mo	Ti	C	Al	Si	Mn
51.75	17.00	5.11	2.93	1.04	0.042	0.41	0.21	0.03

Table 3 Physical and mechanical properties of the materials used

Yield strength σ_s（MPa）	Tensile strength σ_b (MPa)	Elongation δ（%）	Cross-section contraction ratio φ（%）	Hardness HBS
1260	1430	24	40	390

Experimental system.The experimental system was shown in Fig. 1and Fig2. The cutting test was proposed in single-factor method. The cutting force is measured by piezoelectric dynamometer and Charge Amplifier YE5850 produced by Dalian University of Technology,China. The tool wear VB was measured by CCD microscope showed in Fig.3.

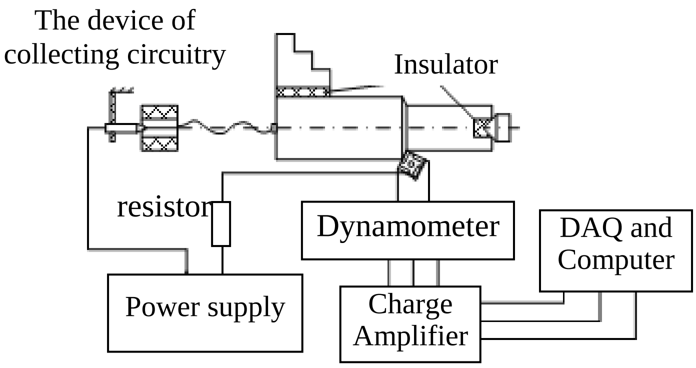


Fig.1 The Schematic illustration of the experimental system

Fig.2 The experimental system

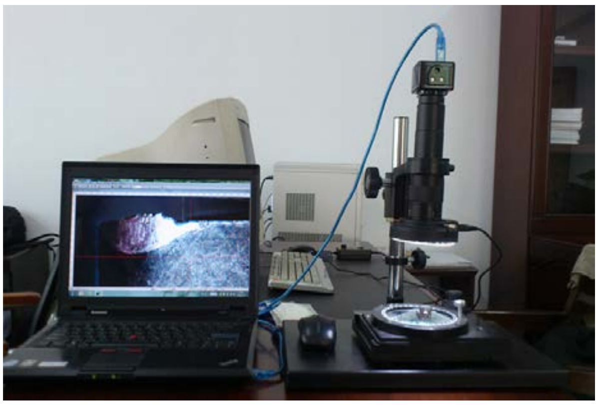


Fig.3 The experimental system

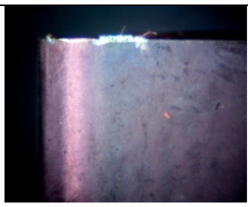
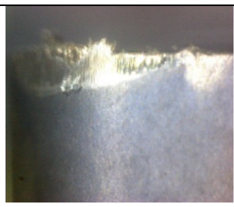
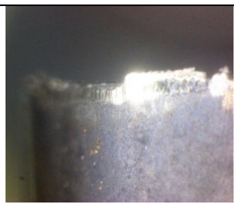
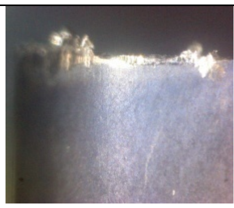
One output of the dc power supply was connected to the workpiece while the other output was connected to the tool, both of them were insulated from the machine, and there was a 1000 Ohm resistor in circuit to limit the electric current. The insert connected with the anode of power supply was labeled “+” and when the insert was connected to the cathode of the power supply was labeled as “-”.The currents applied were +1V,+5V, +10V and -1V,-5V, -10V.

The tool wear tests was carried out with a 0.1mm depth of cut at 60 m/min cutting speed and 0.1 mm/rev feed. The tests were stopped after 10, 30, 60 and 90 second to measure insert flank wear using an optical microscope.

Results and discussion

The effect of externally applied voltage on tool flank wear was shown in Table 4. There were obviously adhesive wear and abrasive wear.The flank wear changed in different voltage condition. It means that the direction of current flow affected tool wear. The effect of electric current on tool wear rate is shown in Fig. 4.

Table 4 The effect of the voltage on insert flank wear

Cutting time	10s	30s	60s	90s
Insert cathode -5V				
Insert anode +5V				
0V				

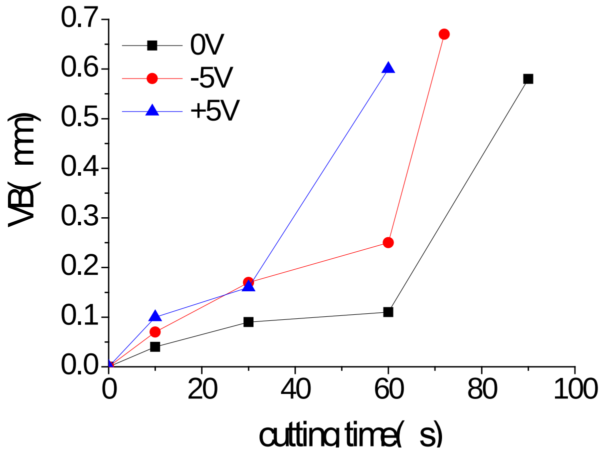
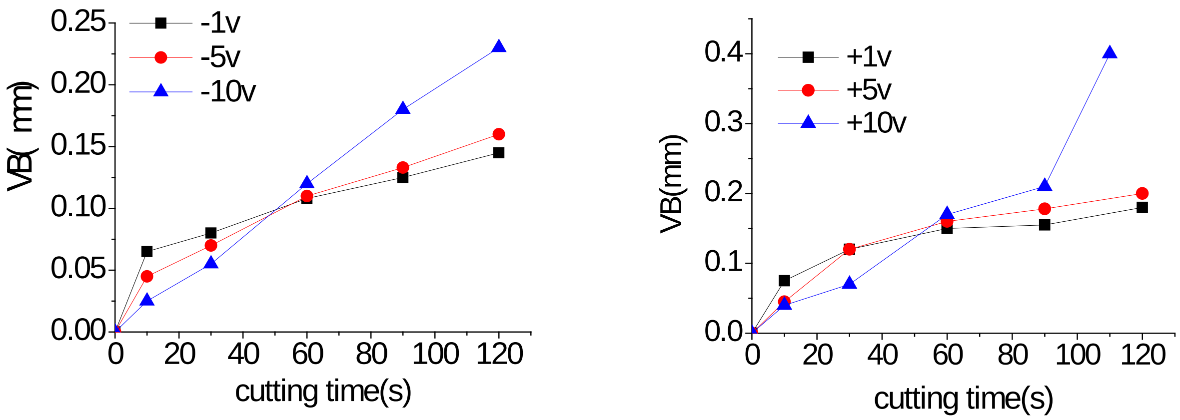


Fig.4 The effect of the voltage on insert flank wear

Fig. 4 shows flank wear of inserts at different applied voltage as a function of cutting time with a 0.1mm depth of cut at 66m/min cutting speed and 0.1 mm/rev feed. Generally, the wear of insert increased as cutting time increased.When the insert was anode, the insert wear was higher than when the insert was cathode and also higher than the condition when no current passed, the wear was least when the insert was no current passed through the contact.

The effect of applied voltage on tool wear rate is shown in Fig. 5.



a)tool cathode b)tool anode

Fig.5 Effect of applied voltage on flank wear

Fig. 5 shows flank wear at different applied voltage 1V, 5V and 10V with a 0.1mm depth of cut at 54.7m/min cutting speed and 0.1 mm/rev feed. It showed that insert wear increased as cutting time increased and changing the voltage affect insert wear significantly. When the insert was cathode, the insert wear was lower than when the insert was anode. Within 50 seconds at the start, the lower the voltage, the faster the tool wear, after 60 seconds, the insert wear increased as applied voltage increased.

Summary

The tool wear tests were carried out to investigate the effect of an externally applied voltage on insert flank wear in turning of Ni-based superalloy GH4169 with coated carbide tool YBG202. The investigation provided some conclusions as follows:

(1)The applied voltage affected the tool wear. When the insert was cathode, the insert wear was lower than when the insert was anode and the insert wear increased as applied voltage increased. When the insert was no externally voltage applied, the wear was least.

(2)The applied voltage significantly accelerated the tool wear due to serious adhesive and abrasive wear,so it should try to avoid applied voltage when cutting nickel-based superalloy in order to reduce tool wear and increase machining efficiency.

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