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# Application of Gas-fluid Atomization Technology in Ultrosonic Vibration Cutting Titanium Alloy Workpiece[1]

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Abstract—To further improve machined surface quality of diamond cutting titanium workpiece and reduce diamond tool wear, it puts forward a kind of machining technology with mixture of carbon dioxide gas, water and vegetable oil atomized mist as cooling media in the paper. The cooling media is sprayed to cutting area through gas-liquid atomizer device to achieve purpose of cooling, lubricating, and protecting diamond tool. Experiments indicate that carbon dioxide gas can touch cutting surface more adequately through using gas-liquid atomization technology, which makes iron atoms of cutting surface cause a chemical reaction directly with carbon in carbon dioxide gas and reduce graphitizing degree of diamond tool. Thus, this technology of using gas-liquid atomization and ultrasonic vibration together for cutting Titanium Alloy is able to improve machined surface quality of workpiece and slow of diamond tool wear.

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## INTRODUCTION

With development of technology and production, the application of a new material-Titanium Alloy is increasing day by day. Although this material has good performance, the machining performance is very poor, it is difficult to cut and grind. At present, general tools used to machining Titanium Alloy are unable to meet requirements. However, natural single-crystal diamond is able to be grinded into very sharp edge, which can cut very thin chips and manufacture mirror machining with very ultra-precision and excellent surface quality. However, while cutting Titanium Alloy with diamond tool, the tool often wears so quickly that it is impossible to carry on [1].

Experiments indicate that adopting diamond tool with ultrasonic vibration cutting technology to cut Titanium Alloy can improve surface quality and reduce tool wear [2]. As in process of ultrasonic vibration cutting, cutting is only in 1/3 of the time during the whole vibration circle and doesn't contact the workpiece for the other time. Thus, cutting fluid can fully enter the cutting area, getting cooled and lubricated fully, tool cooling condition gets improved and cutting temperature reduces significantly. At the same time, the pressure of tool also reduced significantly in the process of ultrasonic vibration cutting, thereby reducing the tendency of micro-fracture of the diamond tool along its crystal face [3]. In order to get better cutting test results, adopting mixture of carbon dioxide and cutting liquid as cooling media can make protection gas contact with cutting surface more fully, and iron atoms of cutting surface occurs exchange reaction directly with carbon of protection gas, so as to protect tool more effectively.

## EXPERIMENTS

### *A. Experimental Setup. Experimental Device*

Before presenting the analysis, we describe the experimental setup. The research of ultrasonic vibration device for ultrasonic cutting titanium is shown in Fig. 1: (*1*) yards disk, (*2*) spindle, (*3*) chuck, (*4*) intake-tube, (*5*) transducer, (*6*) gas protective shield, (*7*) ultrasonic vibration tools carrier, (*8*) inductosyn, (*9*) workbench, (*10*) horn, (*11*) workpiece, (*12*) tool. In order to make gas participate better in the cutting, we design a gas protective shield between the workpiece and tool.

[1] The text was submitted by the authors in English.

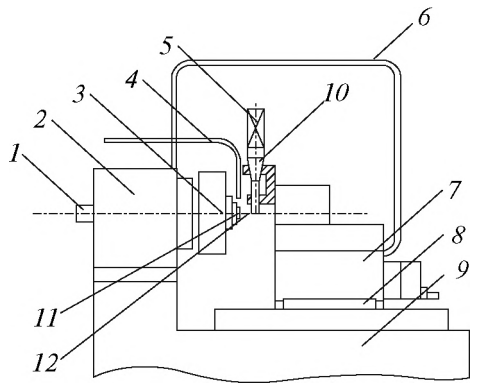


**Fig. 1.** The experimental schematic of application of carbon dioxide in ultrasonic vibration cutting titanium alloy.

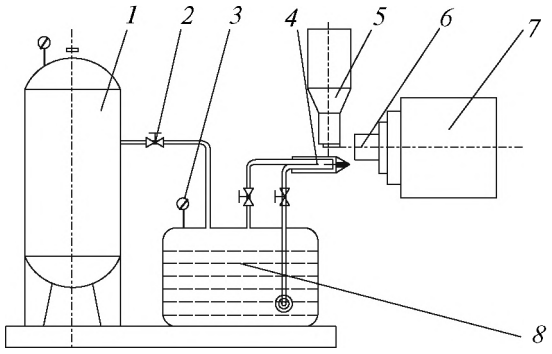


**Fig. 2.** The diagram for gas-fluid atomization device in cutting experiment.

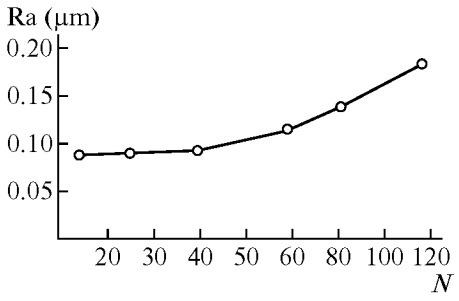


**Fig. 3.** The relation between the quantity of machining parts and roughness in vibration cutting ferrous metals with diamond tool.

### *B. The Research on Carbon Dioxide Gas-liquid Atomization Device*

Metal-cutting fluid plays a very important role in metal-cutting process. Practice has proved that appropriate metal-cutting fluid can reduce cutting temperature 60–150°C, lower surface roughness 1–2 class, reduce cutting resistance 15–30%, improve tool life several fold, sweep iron and gray away from cutting area, thereby, it can significantly enhance productivity and product quality [4, 5]. So it is widely used in machining. Therefore, the appropriate cutting fluid and device used to add cutting fluid would make a great influence on machining result [6]. In the experiment, we choose the mixture of carbon dioxide, water and vegetable oil atomized mist as cutting fluid. Gas-liquid atomization device as shown in Fig. 2: (*1*) carbon dioxide gas tank, (*2*) one-way valves, (*3*) manometers, (*4*) gas-liquid atomizer, (*5*) ultrasonic vibration tools carrier, (*6*) workpiece, (*7*) machine, (*8*) reservoir.

### *C. Experimental Conditions*

Machine Tools: transformed SI-222 precision lathe disk machine tools.

Workpiece Material: Titanium Alloy (TA7).

Tools: natural diamond tools (anterior angle is 0°, posterior angle is 3°, corner radius is 0.8 mm).

Workpiece diameter: 15 mm

Cutting parameters: spindle speed 180 r/min, feed 10 μm/r, depth of cut 4 μm.

Tools vibration frequency: 20 kHz.

Amplitude: 7 μm.

### *D. Experiment. The Experimental Result Without Protection of Carbon Dioxide in Ultrasonic Vibration Cutting*

In ultrasonic vibration manufacturing, closing carbon dioxide intake valves, only letting cutting fluid come through Gas-liquid atomizer, we can get relation between the quantity of machining parts and roughness in vibration cutting ferrous metals with diamond as well as relation between quantity of machining parts and abrasion on tools in vibration cutting ferrous metals with diamond.

### *E. The Experimental Result with Protection of Carbon Dioxide Gas in Ultrasonic Vibration Cutting*

In ultrasonic vibration manufacturing, opening carbon dioxide intake valves, adjusting pressure and making sure cutting fluid which comes through Gas-liquid atomizer is mist, we can get relation between quantity of Machining parts and roughness in the system of carbon-saturated vibration cutting ferrous metals with diamond as well as relation between amplitude and abrasion on tools in system of carbon-saturated vibration cutting ferrous metals with diamond.

## ANALYSIS OF EXPERIMENTAL RESULT

Comparing Fig. 3–6, we conclude that if admitting carbon dioxide gas through Gas-liquid atomizer, using natural single-crystal diamond ultrasonic vibration cutting titanium parts, part surface roughness had a greater improvement; tools wear significantly reduced. From Fig. 5 and 6 we can see that after cutting 120 parts, the surface roughness Ra was less than 0.15 μm.

The bandwidth flank wear was less than 5 μm. The experimental results had such a good result because of follows:

### *A. Carbon Dioxide Gas Is Able to Fully Infiltrate Cutting Area*

As ordinary cutting, chip always forms a high temperature and high pressure zone in tools surface before knife, cutting fluid is difficult to gain access to cutting area, only taking an indirect cooling effect from external tools. While using vibration cutting, due to intermittent form of cutting, when tools separates with part, cutting fluid which flows into cutting area from around, cool and lubricate tip fully. Especially in ultrasonic vibration cutting, due to cavitations formatted by ultrasonic vibration, on one hand it can make cutting fluid emulsified evenly to form a uniform emulsion particle. On the other hand, Cutting fluid material is more easily infiltrated into cracks, which can further improve effect of cutting fluid and conditions of chipping [7].

### *B. Coolant Atomization Is Helpful for Cooling the Tools-part Cutting Area*

The airflow is sprayed through the gas-liquid atomizer device to cutting zone, tiny oil particles of which covers tools, cutting materials and chip to reach purpose of cooling and lubrication. The composite spray machining methods under combined effect of water and cutting plant oil with carbon dioxide gas realize combination of water's cooling function and vegetable cutting oil's lubrication function, which proved that surface roughness under condition of composite spray reduce more than under condition of dry cutting and oil cutting, so it is more stable. After carrying on a series of oil mist lubrication and oil lubrication turning experiments with gas-fluid two-phase flow cooling device, it was proved that this kind of lubrication method has a good effect and is able to effectively reduce tools wear. Atomization cooling cutting area belongs to bubbly vaporization, when fog drop on surface of high temperature, it forms vaporization centers, divorce of bubbles drives fog droplets turning violently, so that it makes fog droplet vaporized further, so taking heat away, as a result, small water droplets generate phase change into steam [8, 9].

### *C. In the Cutting Carbon Dioxide not Only Plays a Cooling Effect, but also Has a Chemical Reaction with Iron Atoms of Workpiece Body, so It Can Protect Tools and Improve Machining Accuracy*

Single-crystal diamond cutting tools will wears while cutting Titanium Alloy, because a variety of mechanisms happen and interact at the same time. The failure mechanism of cutting Titanium Alloy using diamond tools is not overheating, simply wear or mechanical failure as fine cracks, but due to carbon of diamond surface turn into graphite under catalyst of iron.

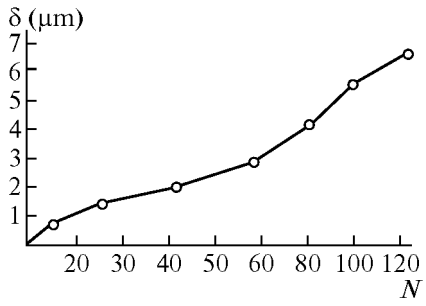


**Fig. 4.** The relation between the quantity of machining parts and abrasion on tools in vibration cutting ferrous metals with diamond tool.

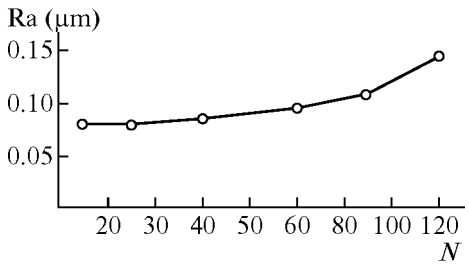


**Fig. 5.** The relation between the quantity of machining parts and roughness in the system of carbon-saturated vibration cutting ferrous metals with diamond tool.

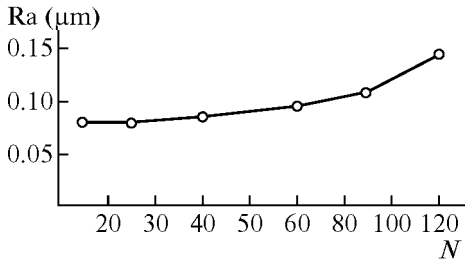


**Fig. 6.** The relation between amplitude and tool wear in the system of carbon-saturated vibration cutting ferrous metals with diamond tool.

Under condition of high temperature and large pressure, diamond will turn into graphite, and iron is one of the most effective catalysts. At high temperatures, surface of diamond tools will oxidize. Under high temperature and pressure, carbon of diamond crystals is easy to decompose and extend to iron-based materials, resulting in "hot corrosion" of diamond. From above wear mechanism, we can see that lowering cutting temperature and pressure to prevent proliferation of carbon atoms can reduce tools wear and prolong cutting tool life.

## CONCLUSIONS

(1) The combination of ultrasonic vibration and gas can significantly slows down degree of diamond tools wear. Under adopted cutting condition, when cutting distance is less than 2000 meters, surface roughness of part Ra is less than 0.15 μm; Bandwidth of flank wear is less than 5 μm.

(2) Using diamond ultrasonic vibration cutting titanium, we can lower cutting temperature and pressure, prevent proliferation of carbon atoms, reduce tools wear and prolong cutting tool life.

(3) When machining titanium alloys using ultrasonic vibration method, adding cutting fluid using Gas-liquid atomization devices can greatly facilitate machining effect.

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