Current Situation of the Use of Cutting Fluids in Machining and Dry Cutting

Jianzhong Zhang[*1], Peng Liu [*2],

School of Mechanical and Electrical Engineering, Shenyang Aerospace University,
NO. 37 Dao Yi South Street North New District of Shenyang, China

[*1]zhangjianzhong9@126.com; [*2]liupenghyyx@163.com;

***Abstract*-Extensive use of cutting fluid causes environmental pollution and increases the processing cost. The improvement of cutting fluid is a serious problem the processing industry faces with. The paper introduces the method of how to improve the cutting fluid and dry cutting that stop using the cutting fluid. Conducted ultrasonic vibration reaming wet and dry experiments, similar to the results of both experiments, the vibration cutting can be realized in dry cutting and cutting quality is better. Dry cutting is a kind of green manufacturing.**

Keywords- Cutting Fluid; Vibration Cutting; Dry Cutting

I. INTRODUCTION

It is particularly important that the development of manufacturing industry is conducive to environmental protection. A country's machinery manufacturing industry is closely related to people's lives. Simultaneously, it reflects the country's industrial level and the comprehensive national strength on a certain extent. But if it is handled properly, the industrial development causing environmental pollution has emerged. The cutting is the most important means of processing machinery manufacturing. To ensure the process runs smoothly cutting fluid is widely used in traditional machining. Statistics show that the consumption of cutting fluid in China is within 700000~850000 tons per year. Obviously in the past few decades, cutting fluid has played an important role in the manufacture industry, and its consumption level is becoming bigger and bigger as well. However, due to the emerging disadvantages of cutting fluid, it is gradually becoming a significant target to reduce the use of cutting fluid or not to use it. Recently, avoiding public hazard, environmental pollution and work disaster to guarantee security and health of human beings have already aroused wide attention of the globe and the whole society. Numerous laws and regulations of international, local and national grade have been established to control the usage of cutting fluid. Taking Germany as an example, strict limitations have been taken to deal with effluent and sweeping. The related laws have increased from 2 in 1950 to 58 in 2006, and it still has further increasing trends. The contradiction between the usage of cutting fluid and environment protection is becoming more evident. Therefore, we have to explore new technique and new technology to protect the environment and resource, and keep sustainable development of human society.

A. The Mechanism of Action of the Cutting Fluid

At first not only good lubrication performance, but also good cooling performance are required, because both friction between cutter and workpiece and the shear plane stress change will produce the heat in traditional cutting process which makes the temperature of cutting zone reach 600-800℃. Secondly because large amounts of debris and dust which is produced during the machining influence the properties of cutting tool, the good cleaning and chip removal function is also required. In addition, cutting fluid remains in the fresh surface that after machining, and directly contacts with cutting tools and machine tool. In order to make them do not rust, good anti-rust function is required in the cutting fluid. To sum up, cutting fluid in cutting process is the role of lubrication, cooling, cleaning dust, rust- proof.

B. The Dangers of Cutting Fluid

1) Harm to Workers' Health

There are a lot of additives in cutting fluid including phenol class material, sodium nitrite(Under certain conditions, with an ammonium salt to generate carcinogenic substances), formaldehyde and other toxic substances that will be harmful to workers' skin and respiratory system, etc;

2) The Higher Costs

Extensive use of cutting fluid will consume a lot of electricity which increases costs, there are more than 3 billion degrees of electricity consume in mechanical industry in China every year, more than 60% is consumed in all kinds of cutting machine, the consumption depends largely on the quality of the cutting oil and lubricating oil and using technical level.

3) The Environmental Pollution

Due to insufficient attention to the harm of waste liquid in the past, the waste liquid usually discharged directly without

treatment. Oil-based cutting fluid which is difficult to be degraded will remain in soil and water. So the rivers and lakes, underground water are subject to different degrees of pollution. It is serious impact on people's life.

II. IMPROVEMENT MEASURES

For the moment the existence of the cutting fluid has a certain value. Because the green manufacturing puts forward the new requirements to mechanical processing, scholars at home and abroad do a lot of research on improvement of the cutting fluid and the change of cutting way.

A. Cutting Fluid's Own Improvement

Chen Zhan, Wang Jiaxu developed a new type of environment-friendly water-base cutting fluid. The main components include nonionic surfactant H, extreme pressure antiwear additive, preservative, clean agent(anionic surfactant Tx-10) and antifoaming agent(silicone oil emulsion) etc. Nonionic surfactant H is synthesized from rosin and polybasic amine and has anti-rust function itself. Other components are commercially available, each distribution is selected by experiment. The new type of cutting fluid is measured according to national standard GB6144-85, all indexes reach or exceed the national standard requirements for water-based synthetic cutting fluid. And the new environmental protection water-based cutting fluid does not contain sodium nitrite which is harmful to human body. The waste liquid is treated easily and friendly to the environment. It has very important significance to the environmental protection.

B. The Optimization of the Cutting Fluid Supply System

Traditional methods of supply liquid include casting method, pressure injection method and spray method, etc. It is very difficult to adjust the dosage of cutting fluid when processing conditions changed. The precision of coolant pump and hydraulic valve which are equipped in the traditional supply system is bad. It is difficult to accurately control the supply of cutting fluid. And the spray nozzles do not meet the requirements of moisture uniformity and oiling accurate. To solve above problems, we improve the supply system:

1) The Rational Use Nozzles in Quantity and Various Forms

In order to make the cutting fluid using more fully, we can use more than one nozzle or different forms of nozzles. For example, we can install two nozzles when turning (as shown in Figure 1) to make the cutting fluid better into the cutting zone [6].We can install two nozzles during milling, one side of the nozzle to make cutting fluid in cutting zone, another side of the nozzle to remove scraps. If the width of cutting tool is narrow, using the round nozzle; If the width of cutting tool is large, then using fan nozzle will be better. Fully using the cutting fluid is saving cutting fluid.

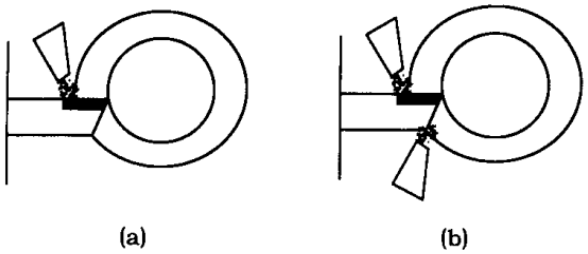

Fig. 1 Nozzles used when turning

2) Using External Spray Cooling and Lubrication System

This system can put micron size coolant spray to the processing area to cooling and lubrication. This slight spray technology can greatly reduce the dosage of cutting fluid（10~100ml/h）. If the structure of spindle can be changed, through the hole in the middle of the spindle or the cutting tool sent cutting fluid to the cutting edge will achieve better effect.

C. Technology of Pruification Treatment of Cutting Fluid

In order to save costs, the cooling liquid is recycled. Used coolant must be purified. Purification includes filtration, sterilization and so on. Guo Cheng and others with diatomite deep layer filtration method do the experiment of filter grinding fluid that is used for CBN grinding wheel in ultra-high speed grinding, and the results showed the high efficiency and precision of diatomite filtration. It is suitable for filtering the cutting fluid of colloidal and viscous material. Xi'an Technological University developed a purification device that does not discharge the cooling liquid. The device is mainly composed of permanent magnet separator and ozone sterilizer. Eliminating environmental pollution is caused by coolant emissions.

D. The Change of Cutting Way

The dry cutting refers to that in the mechanical processing we consciously reduce or do not use cutting fluid in order to protect the environment and save costs. So dry cutting can be divided into near dry cutting that use trace lubricant and dry cutting that does not use cutting fluid completely.

1) MQL Technology of Near Dry Cutting Technology

The research of near dry cutting at home and abroad mainly focus on the technology of atomization cooling lubrication, technology of cryogenic cutting (technology of liquid nitrogen and cold blast cooling lubrication cutting) and minimum quantity lubrication technology, etc. The scholars at home and abroad pay more attention to minimal quantities of lubricant (MQL) cutting technology. It mixed compressed air and a small amount of lubricant together. Atomized the mixture to millimeter, micron sized droplets, and then spray them to the cutting zone, cooling and lubrication of the tool and workpiece. The technology to be able to use the minimum cutting fluid to achieve best cutting work condition neither shortens tool life nor affects processing surface quality. In general situation, the amount of lubricant used by MQL is 0.03-0.2L/min, but when a typical machining center is in the wet-cutting, the amount of cutting fluid is 20-100L/min. The MQL technology is suitable for the conditions that are not fully realized by dry cutting, such as grinding and machining of difficult processing material.

MQL technology lubricating methods have two main ways: external lubrication cooling and internal lubrication cooling. Aerosol external lubrication is to send the cooling fluid into the spray cooling system and mixed with air, under high pressure through a long spray nozzle continuous spray micro, millimeter level of aerosol to the tool surface for lubrication and cooling cutting tool; Aerosol internal cooling way is directly through the spindle and the tool deliver the aerosol cooling into the cutting area for cooling and lubrication. The flow rate of cutting fluid is controlled by the CNC program. If the flow rate is controlled properly, the cutting tool, workpiece and chip are all dry after processing. It is easy recycling and avoids the pollution to the environment.

MQL also meet some problems in implementation: (a) The choice of the ways of cooling. Internal lubrication method is more effective than external lubrication method, but the internal lubrication cutter structure is more complex, which requires both reasonable selection and collocation. (b) The problem of the fog particles diameter control. MQL consumes only a few milliliter of lubricant per hour, so we will strictly control the size of the diameter of the fog particles. And the smaller fog particle is, the better the cooling effect is. But it is difficult to form micron grade particles, so how to form micro and nanoscale particles also needs further study. (c) The problem of how to control oil particles content in air. Reasonable choice of lubricanting oil is also very important. MQL lubricant should use lipids lubricating oil which has good biodegradability, high bearing capacity, less evaporation loss, and superior oxidation stability.

2) High-speed Dry Cutting of Dry Cutting Technology

High speed cutting is a rapid development of new and high technology in today's world manufacturing industry, whose characteristics of high efficiency and high cutting precision are obvious. It is combined with dry cutting of green cutting produce high-speed dry cutting. High-speed dry cutting uses a high efficiency of high speed numerical control processing means to gain high precision, high flexibility, at the same time, the use of cutting fluid is limited, and is an advanced manufacturing technology conforming to the sustainable development. It is not simple to improve the cutting speed and stop using the cutting fluid, and reasonable improvement of cutting tools and machine tool and research of key technology is the key of this technology. The Makino company proposes “Red Crescent” dry cutting process. Its mechanism is that due to the high speed cutting without cutting fluid, the front of tool will gather a lot of cutting heat, then the workpiece material near the cutting zone will be the status of red-hot, which leads to the obvious decrease of the yield strength to improve the material removal rate.

In high-speed cutting process, most of the cutting heat is bored by the chip and tool, the chip departs from workpiece quickly and takes away part of the heat, but the cutting tool is sustained cutting heat and cutting force, so it needs the cutting tool to have the ability of high hardness and high temperature stability. Coated tools are suitable for high speed dry cutting. The tool through the coating treatment can achieve solid lubrication, reduce friction, to reduce heat of tool absorbed. It can withstand high cutting temperature. Composite coating tools both have high hardness and high wear resistance of "hard" coating materials, and self-lubricating properties of "soft" coating materials, make the performance of cutting tool more superior. Besides the technology also has certain requirements to machine tools, one is the rapid conduction of heat cutting another is the rapid discharge of chips. If necessary, a vacuum suction device should be designed. Not all workpiece can be processed by high-speed dry cutting, especially high-temperature alloys. It is suitable for cutting soft materials, such as cast iron, aluminum alloy etc. Only the comprehensive development of the machine tools, cutting tool material and coated tool can make the promotion and development of this technology.

III. ULTRASONIC VIBRATION CUTTING TOOLS FOR DRY CUTTING

Ultrasonic vibration cutting technology was put forward in 1950 by Japanese scholar Kumabe Junichiro. Then the United States and the former Soviet Union, Britain and Germany did a lot of researches on vibration cutting, and made great progress. The cutting effect of traditional cutting can not be compared with it. Ultrasonic vibration cutting has a superior cutting mechanism; the cutting process is room-temperature that shows the insensitivity of coolant. Therefore it can realize real significance of dry cutting. We studied the ultrasonic vibration cutting, conducted the ultrasonic vibration dry cutting test, got the good processing effect, and the cutting tools almost no wear and tear.

A. The Mechanism of Ultrasonic Vibration Cutting

As shown in Figure 2, the tool is imposed on ultrasonic wave to produce vibration along the host cutting movement direction, formed the separation type of vibration cutting affected by waveform of pulse force. Dynamic analysis shows its insensitiveness vibration cutting properties. The pulse force vibration cutting eliminates the microscopic elastic vibration in the traditional process of cutting, the cutting process is very stable, changed the extrusion of cutting edge act on ablation zone of workpiece into almost pure cutting process, cutting deformation is minimal shrinkage coefficient is approximation equal to one, Cutting force is only 1/10-1/3 of the normal cutting ; Graph of cutting zone temperature is pulse shape, so average cutting temperature is very low, producing little cutting heat, cutting process at room temperature, the tools rarely wear. Machine surface is composed of numerous tiny flat or curved forming a beautiful pattern.

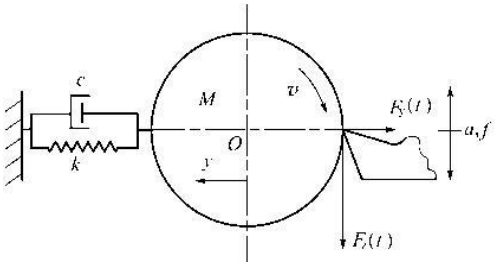

Fig. 2 Waveform pulse force vibration cutting

B. The Characteristics of Ultrasonic Vibration Cutting

Machining surface roughness is low, it can replay grinding with turning ; Machine surface cold-work hardening is greatly reduced; it can greatly improve machining precision of processing; Effect of ultrasonic vibration cutting almost has nothing to do with the material of workpieces. Because the cutting force is pulsed, the average cutting force is small. It can process difficult materials, such as titanium, high-temperature alloys, high strength steel etc which to a large extent make the system rigidization.

Because vibration cutting is an advanced processing technology, vibration parameters on workpiece quality are very large, but also according to different processing objects of different materials to make corresponding changes. Therefore, the modified cutting equipment can not achieve this goal. It must increase the automatic control system of changing vibration parameters to realize automation and intelligence of vibration cutting.

C. Dry-type and Wet-type Ultrasonic Vibration Reaming Experiment

In the experiments，the ultrasonic generator with automatic frequency tracking performance output power 0~500W, frequency was 16~23kHz. The reaming tool with special tool(as shown in Figure 3) to ream beforehand processed Φ7.6 mm ,80 mm deep bottom outlet with dry-type and wet-type ultrasonic vibration method. The L1 part is Φ8 standard twist drill drilling welding with steel 45, the length of L should satisfy the resonance condition. In order to guarantee the cutting part of the reamer cutter and Morse taper coaxia, it shall be in reaming cutting part positioning processing Morse taper after welding. Machined material is 45 steel.

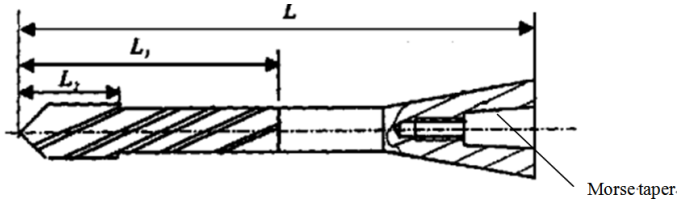

Fig. 3 Schematic diagram of reaming structure

D. Ultrasonic Vibration Machining Precision of the Reaming

Under conditions of that the speed of tool is 292r/min and feed rate is 0.1 mm/r to processing, after processing the roundness and cylindricity of the hole are less than 0.01mm. Diameter of hole is 0.02 mm bigger than diameter of reaming cutter. Test surface roughness of the specimen by surface profiler, the Ra value of wet-cutting is 0.6μm, the Ra value of dry-cutting is 0.7μm. There are no scratch and indentation on the machine surface. Experiment shows that precision and the surface roughness of dry-cutting is not worse than wet-cutting's. Their chips are all at room- temperature. Therefore, ultrasonic vibration cutting can realize the real meaning of dry cutting.

IV. CONCLUSIONS

Green manufacturing which is a new type of modern manufacturing mode synthetically considers environmental impact

and resource efficiency. This article mentioned the improvement of cutting fluid and supply systems, which meet the requirement of green manufacturing, but cannot fully replace the existing cutting fluid. The dry cutting technology which does not use cutting fluid can fundamentally solve the problem of cutting fluid. Neari-dry machining, high-speed dry cutting have their advantages but also have limitations. By contrast, ultrasonic vibration dry cutting, whether from cutting materials and cutting quality are superior. It should be vigorously promoted and developed.

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