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A REVIEW OF NON CONVENTIONAL METHODS OF COOLING CUTTING TOOL

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ABSTRACT

As the temperature of cutting tool may reach to high, in particular mechanical processes. When a heavy cut is taken at large speed, coolant is necessary to prevent thermal damages and tool wear. As liquid coolants are commonly mineral oil based and they represent dangerous effects on environment and toxic for the operator. In many machining processes cooling is achieved using oil based fluid. Cutting fluid is used to reduce cutting force, to lower the cutting temperature, to prolonged tool life and enhance machining efficiency and also achive surface finish quality during machining. The better the performance of cutting fluid and less pollution effect on environment.In 21st century with environment protection awareness and enhanced regulations in forced, green cutting has become a general trend in machining. Green cutting becomes focus on attention in ecological and environmental protection. By using steam or air jet as coolant is cheap, pollution free, eco-friendly and then is a good an economical coolant and lubricant.The experiment result shows with steam or supersonic air jet as coolant and lubricant, gradual reduction in cutting force, friction coefficient, cutting temperature and reduction in built in edge formation. Advanced material such as aero engine alloy and hardened steel provide serious change for cutting tool material due to high temperature. The purposes of these techniques are to investigate the use of supersonic air jet can be used in many situations for thermal and mechanical point of view, where liquid cannot and therefore there are environmental benefits. The motivations for using green cutting techniques are not only an environmental and economic consideration but also this approach has also technological benefit.

Keywords: Non-conventional techniques, optimization, cutting parameters, machining operation.

I. INTRODUCTION

Cutting fluid is usually used to reduce cutting force, lower cutting temperature, prolong tool life and enhance machining efficiency and surface finish quality during machining. In general, the better the performance of cutting fluid, the more pollutant it is to the environment. In the 21st century, with environment protection awareness enhanced and laws and regulations enforced, green cutting has become a general trend in machining [1]. In the 1990s, Podgorkv V.V. and Godelvski V.A. proposed a new and pollution-free green cutting technique with water vapor as coolant and lubricant during cutting process [2,3]. In The result shows that the cutting force is reduced; the friction coefficient, the deformation coefficient and the surface roughness value R_a are decreased and the cutting temperature is lowed.

Cutting fluids can decrease the temperature in cutting zone and cutting forces, consequently extend the tool life. Unfortunately, conventional cutting fluids cause environment and health problems. Pollution generated during machining mainly come from waste cutting fluids. The recycling and disposal of waste cutting fluids is about 16–20% of machining costs [2]. Green cutting is becoming more popular due to the safety of the environment and human health concerns. There is a need to find a new cooling and lubricating technology that can alleviate pollution to environment and harm to the operator, and the lubricants need not be recycled and disposed. This is a pollution-free and ecofriendly green cutting technology.

II. LITERATURE REVIEW

The application of gases as cutting fluids has been used since 1930s. Pahlitzch, Hollis and Cakir reported the experimental results of carbon dioxide gas application in machining. It was noticed that application of carbon dioxide gas as coolants and lubricants reduced the cutting force and obtained a higher tool life [6,7]. Axer, Rowe, Smart, Johansson, Willams, Tabor and Cakir et al. also deeply studied application of oxygen gas as cutting fluids in cutting process [8–14]. Rowe and Smart observed these results were promising that the application of oxygen gas was an effective agent to reduce contact length of tool–chip [10]. However, Axer proposed the application of oxygen caused shorter tool life [10]. Williams and Tabor examined oxygen gas effect as a lubricant. It was noticed that the use of oxygen reduced cutting forces. As a result, a better surface quality occurred [12–13]. In the 1990s, Podgorkov and Godlevski used water vapor as coolants and lubricants in turning and milling operation. The results showed water vapor lubrication in comparison with liquid one ensures more uniform cooling and the application of vaporous lubrication allows to increase the carbide cutting tools lifetime about 2–2.5 times in turning and 2–4 times in milling carbon and stainless steels [3,4]. But there have been very few researches examined the effects of the application of mixture of water vapor and gases as coolants and lubricants.

III.CONSTRUCTION

Cutting fluids are very important in machining processes. They are used to reduce the effects of friction. They are also used to carry away heat in machining operations. Excessive heat can damage the microstructure of metals. Proper use of coolants can make higher metal removal rates possible. Coolants can also help improve part quality and dimensional accuracy.There is a wide variety of cutting fluids available today. Many new coolants have been developed to meet the needs of new materials, new cutting tools, and new coatings on cutting tools. The goal of machining operations must be to improve productivity and reduce costs. This is accomplished by machining at the highest practical speed while maintaining practical tool life, reducing scrap, and producing parts with the desired surface quality. Proper selection and use of cutting fluids can help achieve all of these goals.

In machining almost all of the energy expended in cutting is transformed into heat. The deformation of the metal to create chips and the friction of the chip sliding across the cutting tool produce heat. The primary function of cutting fluids is to cool the tool, work piece, and chip, reduce friction at the sliding contacts, and prevent or reduce the welding or adhesion on the contact edges that causes a built-up edge on the cutting tool or insert. Cutting fluids also help prevent rust and corrosion and flush chips away.

3.1. Cutting Fluid Purposes

3.1.1 Cooling

Machining operations create heat. This heat must be removed from the process. The chip helps carry away heat from the tool and work piece. Coolant takes heat from the chips tool, and work piece. To be effective the fluid must be able to transfer heat very rapidly. The fluid absorbs the heat and carries it away.

3.1.2 Lubrication

In a typical machining operation, two-thirds of the heat is created by the resistance of the work piece atoms to being sheared. The friction of the chip sliding over the cutting tool face creates the other one-third of the heat.

Cutting fluid with good lubrication qualities can reduce the friction of the chip sliding over the tool face. The lubrication actually changes the shear angle, which reduces the shear path and produces a thinner chip. Good lubrication also reduces internal friction and heat through less molecular disturbance.

3.2.Water Miscible Cutting Fluids

3.2.1 Emulsions

Emulsion is a term that describes soluble oils. An emulsion is a suspension of oil droplets in water. Soluble oils are mineral oils that contain emulsifiers. Emulsifiers are soap-like materials that allow the oil to mix with water. Emulsions (soluble oils) when mixed with water produce a milky white coolant. Lean concentrations (more water-less oil) provide better cooling but less lubrication. Rich concentrations (less water- more oil) have better lubrication qualities but poorer cooling.There are different types of soluble cutting fluids available including extreme pressure soluble oils. These should be used for extreme machining conditions where it is necessary to reduce friction where the tool and work piece contact each other.

3.2.2 Semi-chemical Coolants

Semi-chemical fluids are a combination of a chemical fluid and an emulsion. They have a lower oil content but more emulsifier. This makes the oil droplets much smaller. They have moderate lubrication and cooling and high rust inhibition properties. Sulfur, chlorine, and phosphorous are sometimes added to improve the extreme pressure characteristics.

3.2.3 Straight Cutting Oils

Straight cutting oils are not mixed with water. Cutting oils are generally mixtures of mineral oil and animal, vegetable, or marine oils to improve the wetting and lubricating properties. Sulfur, chlorine, and phosphorous compounds are sometimes added to improve the lubrication qualities of the fluid for extreme pressure applications. There are two main types of straight oils: active and inactive.

3.2.4 Inactive Straight Cutting Oils

Inactive oils contain sulfur that is very firmly attached to the oil. Very little sulfur is released in the machining process to react with the work piece. Mineral oils are an example of straight oils. Mineral oils provides excellent lubrication, but are not very good at heat dissipation (removing heat from the cutting tool and work piece). Mineral oils are particularly suited to nonferrous materials, such as aluminum, brass, and magnesium. Blends of mineral oils are also used in grinding operations to produce high surface finishes on ferrous and nonferrous materials.

IV. WORKING

4.1. Vapor generator and vapor feeding system

The water vapor generator and vapor feeding system are developed in which jet flow parameters (pressure, tempera-ture, flow velocity and humidity) and cooling distance (it is the distance between nozzle and cutting zone) are controllable. Fig. 1 shows the principle of mechanism and Fig. 2 shows the water vapor generator and vapor feeding system.

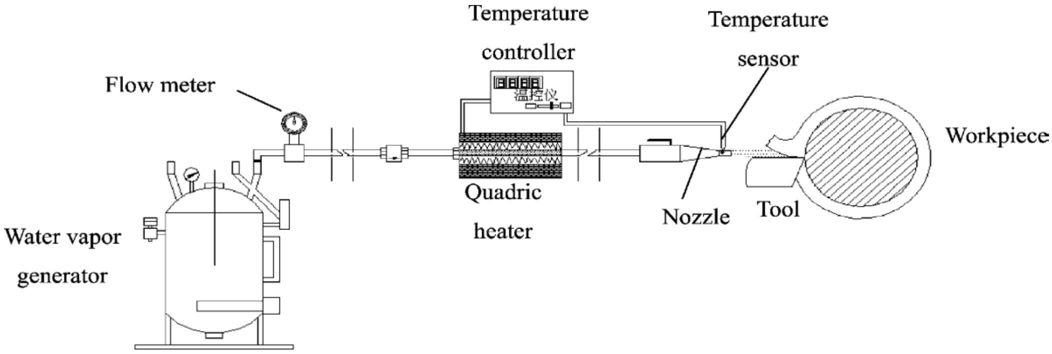


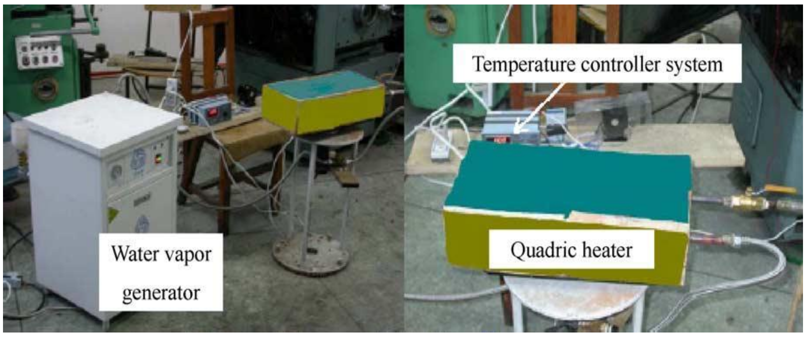
Fig. 1. The principle skeleton of vapor generator device and vapor feeding system.

4.2. The simulation of distribution of temperature and velocity

The temperature and velocity of vapor jet flow directly influence lubricating and cooling effect. Through measuring velocity of nozzle and temperature values in different locations in the cooling distance, the distribution of temperature and velocity are modeled in space by Matlab with different colors standing for different values of temperature and velocity. Figs. 3 and 4 show the simulated results when the temperature is controlled at 110 8C of the 3 mm nozzle in diameter.

4.3. Cutting experiments

Experiments were carried out on CA6140 lathe with hard alloy YT15 of variable-positions at cutting tool and the C45 steel as working material. The quantity in cutting should be reasonably selected to obtain good working quality during cutting. Table 1 shows the cutting parameters and lubricat-ing condition parameters for secondary precision cutting. The cutting force is measured by Vertical Parallel Octagon resistance strain turning dynamometer and the cutting temperature is measured by tool-workpiece thermo-couple method. Surface roughness R_a is measured comparison with standard surface roughness mass. The experimental system is shown in Fig.



V.DISCUSSION

5.1. Main cutting force Fc

The main cutting force of water vapor, carbon dioxide gas, oxygen gas and mixture of vapor and gas applications, dry cutting and wet machining are illustrated due to depth of cut in Fig. 05. The main cutting force Fc increases with growth of the depth of cut, and the Fc of dry cutting is larger than wet machining.The Fc has been reduced with dependent on applications of water vapor, gases and mixture of vapor and gas. Similarly, these applications reduce the Fc, and WV&C reduces much lower with lager depth of cut ap than other applications. Results indicate that the Fc is reduced respectively less about 20–40% and 10–15% with application of water vapor, gas and mixture of vapor and gas as lubricant than dry cutting and wet vcutting. It also can be known from Figs. water vapor and mixture of vapor and gas form high speed jet flow by nozzle, vand they will fill up the capillaries of tool–chip interface in stead gaseous state, and high temperature vapor or mixture steam will easily form boundary lubricating layer with higher adsorption strength .

5.2. The cutting temperature θ

The cutting temperature θ is measured by thermal couple method. Fig. 06shows the θ comparison with different lubricating conditions. It will be increased little with the depth of cut ap increasing. Applications of water vapor, gases and mixture of vapor and gas reduce the θ much lower than dry cutting. In general, the cutting fluids mainly depend on heat convection to reduce the cutting temperature in machining. As water vapor, gases and mixture vapor steam can reduce the contact friction of tool–chip interface with high efficiency lubricating action, which lead to the energy of plastic deformation and friction of tool–chip interface consumption lowered, and they have indirectly cooling effect. Therefore, under the conditions double function of indirect cooling and heat convection by applications of water vapor, gases and mixture steam, the cutting temperature is decreased much more than dry cutting. As water vapor has an excellent thermal–physical property that it effectively lowered the cutting temperature comparing to other lubricating conditions.

5.3. The chip deformation coefficient Λh

Through measuring the chip thickness by metrology microscope, the Λh is obtained by calculation with formulation Λh = $h$ch/hD, (where chip layer thickness hD = f sin kr, and kr is certain) [06]. Λh can directly reflect the extent of chip deformation and the friction status. If the value Λh is smaller, the chip thickness will be thinner and the lubrication status will be better in tool–chip interface. Fig. 07 shows the comparisons of Λh with different lubrication conditions. The chip deformation Λh is the smallest with water vapor as coolant and lubricant because the chip coil is increased and the length of tool–chip is reduced when the vapor jet flow ejects on the tool–chip interface, and the friction condition of tool–chip interface is improved. The chip deformation coefficientΛh is reduced much in compare to other lubrication conditions and dry cutting.

5.4. The maximum width of tool flank wear land VBmax

As the intense friction is presented in the interface between the finished surface and tool flank, the tool flank near the cutting edge will be quickly wear and form the tool flank wear land. When the chip flows along the tool rake face, the crater wear will be observed.fig. shows the cutting-tool wear in rake face and tool flank. The tool flank wear is not uniform in the cutting edge, and there are three wear regions in tool flank wear.

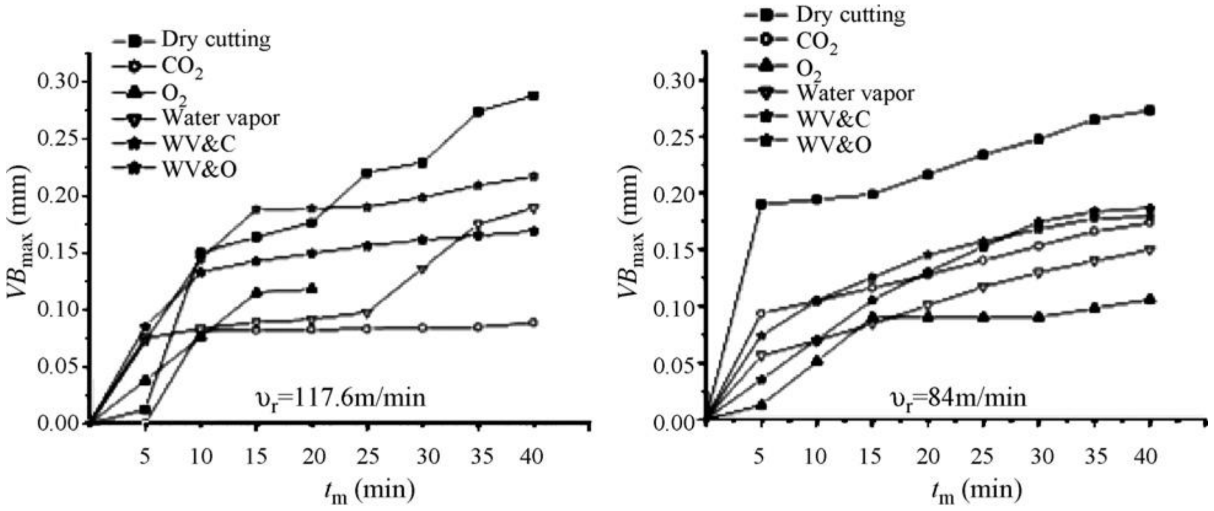


Fig. 09. The relation cure between maximum attrition widths VBmax and cutting time.

5.5. The wear of tool rake face

In general, the crater abrasion is formed on the tool rake face in dry cutting. Fig. 19 shows the wear morphosis of tool rake face with different lubrication conditions and cutting speed varied. The crater abrasion can be found at moderate and lower cutting speed and the main cutting edge has been worn out at high cutting speed in shorten time during dry cutting. The crater abrasion is also found on tool rake face at higher cutting speed with application of carbon dioxide gas. There are many adhesions with application of oxygen gas. The tool rake face occur adhe adhesion wear and abrasive wear with applications of water vapor and mixture of vapor and gas.

5.6. Tool wear analysis

In order to research tool wear mechanism, the tool–chip contact region of tool rake face is detected by SEM and EDS. Fig. 09 shows the detection region in tool rake face.

Fig. 09 shows the micro-pattern of detection region of tool–chip contact and Fig. 09 shows the chemical element analysis results of tool–chip contact region by EDS. Fig. 23 shows

comparisons of main chemical element content with different cutting speed under different lubrication conditions. It can be known that the main wear mechanisms of a metal cutting tool are abrasive wear, adhesive wear and diffusion wear. Trent [09] has shown that the wear process in the crater of cemented carbide cutting tools is one in which the metal and carbon atoms of the tool diffuse into the workpiece material and are carried away in the chip, the diffusion wear is dominated at higher cutting speed and adhesion wear is dominated at lower cutting speed. When the cutting speed was higher (υc = 117.6 m/min) the cutting temperature is higher (>800 ◦C) with applications of other lubrication conditions except for application of water vapor as coolants and lubricants. When water vapor was as coolants and lubricants, the cutting temperature is lower (<800 ◦C at cutting speed υc = 117.6 m/min) than other lubrication conditions.

VI. LUBRICATION AND MECHANISM

As research shows, there are several mechanisms to explain cutting fluid access to tool–chip interface, which are shown in Fig. 1a [6]. Most specialists consider that cutting fluid accesses the cutting zone through the kinetic action of capillary network existing in tool–chip interface and forms firmer lubrication film by physical and chemical adsorption on the capillary wall. A geometric model of single capillary is shown in Fig. 13b and it is a cylinder with one closed end and one open end.Lubricating action of cutting fluid requires that the cutting fluid absolutely penetrate the capillaries of cutting zone and the penetration time be less than capillary lifetime, that is, there is a storing time (deviation of capillary lifetime and penetration time). The longer the storing time, the better the penetration performance will be. So the research ofthe kinetic model of penetration capillary of water vapor is the basis for analyzing the lubricating and cooling action mechanism.

6.1. Analysis of water vapor jet flow state

The state of water vapor jet flow has direct influence on its cooling and lubricating effect, The critical radius can be calculated by the equilibrium theory of vapor coagulation.

rlj Z

2sTs=rl

DTlCTs=rg

Where rlj is the critical radius of water droplet, s, surface tension of droplet, Ts, saturation temperature, rl, density of liquid, DT, degree of superheat, l, heat of transformation, rg, density of vapor.

6.2. The velocity of penetration capillary and storing time of water vapor

As it can be known by analyzing the lubricating action of cutting fluid, the penetration capillary time has to be less than the capillary lifetime. An important parameter to evaluate lubricating action of water vapor is the average velocity of penetration capillary or the storing time. So the calculating formulation of average velocity of penetration capillary can be proposed by the pneumodynamics equation (ideal gas Euler equation) and energy equilibrium equation (thermokinetics equation)

6.3. The friction force between tool rake face and chip Ff

The cutting fluid depends on penetrating capillary of tool–chip interface and forming lubrication film for reducing the friction between tool rake face and chip during cutting. On the conditions of lubrication action, the friction Fig. 14. The model of penetration capillary of lubricant. (a) The penetration model of liquid, (b) the filling model of water vapor. ll, the infiltration length of liquid; lg, the filling length of gas; lc, the capillary length; r, the capillary radius; ng, the filling velocity of gas; wg, the filling velocity of water vapor

VII. MERITS AND DEMERITS

- **MERITS**

1. Vibration less running of engine
2. Easily engine gets start
3. Emission and Noise is controlled at greater level

- **DEMERITS**

1. Once in year there is requirement of filling of lime water.
2. More requirement of space
3. The weight of silencer get increases

VIII. CONCLUSION

Water vapor is overheated and the vapor temperature is higher than 100 1C before it penetrates the cutting zone. The water vapor is dry and has no water drop, and this leads to easy water vapor penetration in the cutting zone. However, vapor temperature used as coolant and lubricant by V.A. Godlevski and V.V Podgorkov is less than 100 1C before penetrating into the cutting zone. The water vapor is wet and there are few water drops which lead to poor lubricating action. The formation of the boundary lubricating layer process is first investigated, when using the water vapor as coolant and lubricant in cutting ANSI 304 stainless steel.

IX. ACKNOWLEDGEMENT

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