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Review Article

COOLANTS AND THEIR ROLE IN GRINDING

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Abstract: Coolants play a decisive role in grinding because of the intense heat generation and the consequent thermal damage associated with the process. Different types of coolants with varying and diverse compositions are used for grinding different types of work material in order to reduce the heat generated due to friction and to carry away the heat produced as well as for efficient swarf disposal. The present paper aims at discussing about the different types and composition of coolants used in grinding. The mechanism of action of coolants, their application on different workpiece materials and their functions are also discussed in the paper.

Key words: *coolant, lubrication, grinding.*

1. Introduction

Grinding is an essential machining operation employed as a common finishing process in manufacturing. The process of grinding is associated with the generation of high temperature at the grinding zone, which leads to several grinding defects. For controlling the temperature, grinding fluid, also referred to as coolants, are employed [1,2,3].

The distinguishing feature of grinding from other machining processes is the relatively large contact area between the tool and the workpiece and the high friction between the abrasive grits and the workpiece surface. This makes supply of coolant in the grinding zone difficult, thereby resulting in a high risk of thermal damage to the workpiece surface layer and also severe wheel wear and loading.

Cutting fluid is applied primarily to cool and lubricate the cutting region so that generation and accumulation of heat may be reduced. Different types of cutting fluids may have varying degree of effects depending upon the type, composition and properties of the workpiece being ground [4].

Researchers have reported that fluid delivery in grinding zone is obstructed due to the presence of stiff air layer around high velocity grinding wheel. Mandal et al.[5] proved experimentally that more fluid can pass through grinding zone with the use of a pneumatic barrier set up, and this can be used for effective control of grinding temperature. They also developed a multi-nozzle system for delivering grinding fluid which resulted in less wastage of coolant.

In the present paper, a brief review of different types of cutting fluids and their composition have been made. The application of grinding fluids on different workpiece materials and their functions are also discussed.

2. Use of Coolants

Coolants play a decisive role in machining. Appropriate application of coolants results in enhanced process stability, better workpiece quality and tool life. Apart from heat dissipation i.e. cooling, the other main function of a coolant is lubrication which is achieved by reduction of friction at the chip-tool interface and tool-finished surface interface. Carrying away swarfs away from the contact zone is another important function of the coolant. The combined effect of lubrication and cooling reduces tool wear and improves surface quality and dimensional accuracy of the workpiece [4].

3. Mechanism of Action of Cutting Fluids

The tool-chip contact zone (Cn) usually consists of two parts; elastic contact zone (Ce) and plastic/ bulk contact zone (Cp) [6] as shown in Fig.1.

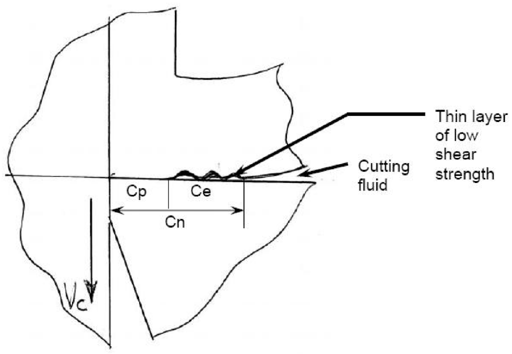

Fig.1 Cutting fluid action in machining.

The cutting fluid, though not able to reach the plastic zone, enters the elastic zone by capillary effect. As the cutting velocity (Vc) increases, the fraction of plastic contact zone gradually increases and ultimately covers the entire chip-tool contact zone as indicated in Fig.2.

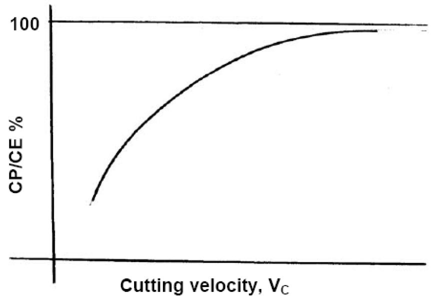

Fig.2 Apportionment of plastic and elastic contact zone with increase in cutting velocity.

Therefore, at high machining speed, the cutting fluid is only able to cool (rather than lubricate) the tool and the workpiece by bulk external cooling.

In grinding, the coolant in the contact zone influences the chip formation process by building up a lubricant film, thus lowering the friction forces and cooling the work material and tool surfaces. As the lubrication effect increases, there is a corresponding increase in elastic-plastic deformation under the cutting edge of the abrasive grain, which results in a decrease in workpiece roughness.

4. Types of Grinding Fluids

i) Cutting oils- These are generally compounds of mineral oil to which requisite amount of vegetable, animal or marine oils are added for enhanced spreading, wetting and lubricating properties. As and when required, some extreme pressure (EP) additive is also mixed to reduce friction and adhesion.

ii) Water- For its good wetting and spreading properties and very high specific heat, water is considered as the best coolant, and hence, employed where cooling is most urgent. However, it reacts with ferrous materials.

iii) Soluble oil- Although water acts as the best coolant, but it cannot lubricate. Moreover machine-fixture-tool-work system exposed to water may get rusted. So, oil containing some emulsifying agent and additive like EPA, together called cutting compound, is mixed with water in proper proportion. This milk like white emulsion, called soluble oil, is very common and widely used in machining and grinding.

iv) Solid or semi-solid lubricant- Waxes, soaps, pastes, graphite, Molybdenum-disulphide (MoS_2) may also often be used, either applied directly to the workpiece or impregnated in the tool to reduce friction, and hence, cutting forces, temperature and tool wear.

v) Cryogenic cutting fluid- Extremely cold (cryogenic) fluids (in the form of liquid or gas) like liquid CO_2 or N_2 are used in some special cases for effective cooling without creating much environmental pollution and health hazards [7,8].

5. Effects of Coolant Composition

Effects of coolant composition on grindability of different materials were examined by several researchers. Brinksmeier’s [9] investigations showed that although converted grinding powers are the same when using non -additive oils and emulsions, emulsions produce higher compressive residual stresses, and hence, lower thermal loading and better heat dissipation. Heuer [10] and Tonshoff et al [11] found that roughness and wear increased with use of polar and chloride additives in comparison to non-additive oil, whereas use of a sulphur additive reduced roughness and tool wear.

As to the effect of additive concentration on process forces, Spur et al. examined the grinding of Inconel with cBN [12]. They showed that an increase in active or inactive sulphur concentration leads at first to a decrease, and then, to an increase in process forces.

Von Brevern [13] showed, that additive oil in comparison to non-additive oil, during grinding of carbides, gave major benefits in the wear of diamond tools and to some extent, in surface roughness.

Torrance [14] and Gibbs [15] showed that the levels of extreme pressure (EP)-additives, containing chloride and sulphur, directly affect the grinding forces. Furthermore, continuous dressing grinding is used for a comparative assessment of different coolant compositions thus excluding the influence of tool wear.

Klocke [16] showed, that with increasing oil content, process forces during thread grinding with cBN decrease.

On the whole, it can be said that selection of the 'best' additive for a machining process is hardly possible.

6. Grinding Fluid Selection

Selection of a grinding fluid depends upon the work-wheel material combination and environmental conditions. As for example, for high speed machining of conventional materials, greater cooling type fluids are preferred and for low speed machining of both conventional and difficult-to-machine materials, greater lubricating type fluid is preferred. Selection of cutting fluid for grinding some common engineering materials is presented as follows:

a) Grey cast iron: Generally dry for its self lubricating property, or air blast for cooling and flushing chips.

b) Steels: If machined by HSS tools, soluble oil (1: 20 ~30) for low carbon and alloy steels and neat oil with EPA for heavy cuts. Often steels are machined dry by carbide tools for preventing thermal shocks.

c) Aluminium and its alloys: Preferably machined dry, otherwise light but oily soluble oil or straight neat oil or kerosene oil for stringent cuts.

d) Copper and its alloys: Water based fluids are generally used, but oil with or without inactive EPA for tougher grades of Cu-alloy are also used.

e) Stainless steels and Heat resistant alloys: High performance soluble oil or neat oil with high concentration with chlorinated EP additive.

7. Conclusion

This paper illustrates the importance of using cutting fluids in a high speed machining process like grinding. Coolant type and composition can amply influence work surface quality and wheel wear. The paper gives an insight into the mechanism of action of coolants in grinding. It also summarizes to some extent the research work performed in the field. All these ideas amply demonstrate the importance of friction, cooling and lubrication in grinding.

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