ECOLOGICAL ASPECTS OF CUTTING FLUIDS & MINIMIZATION OF THE ECOLOGICAL IMPACTS OF CUTTING FLUIDS

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Historically, cutting fluids have been used extensively in metal cutting operations for the last 200 years. In the beginning, cutting fluids consisted of simple oils applied with brushes to lubricate and cool the machine tool. Occasionally, lard, animal fat or whale oil were added to improve the oil's lubricity. As cutting operations became more severe, cutting fluid formulations became more complex. Today's cutting fluids are special blends of chemical additives, lubricants and water formulated to meet the performance demands of the metalworking industry.

WHAT ARE THE FUNCTIONS OF A CUTTING FLUID ?

In order to understand the function of the metal removal fluid, one must understand the process of chip formation. A simple two-dimensional representation of idealized chip formation is shown in Figure 1. Chip formation can be approximated by the shearing and sliding of a series of deformed layers of metal. The region where shearing takes place is known as the shear plane. The sheared metal then slides over the rake face of the cutting tool. In addition to the machined part and chip, one of the primary products of the chip formation process is thermal energy or heat. Temperatures at the cut edge are usually in the range of 260° to 480°C (500° to 800° F) for high speed steel tools and 420° to 650°C (800° to 1200° F) for carbide tools. A metal removal fluid properly applied to the cut zone absorbs the heat and carries it away. During machining, the temperature depends upon the balance between the rate at which heat is generated and the rate the heat is dissipated. As such, it is easy to understand why many on the manufacturing floor refer to metal removal fluids as coolants.

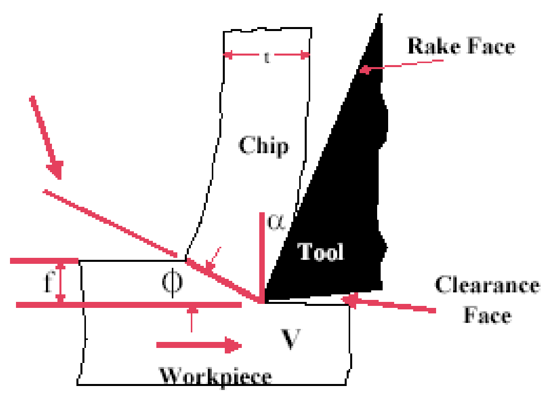

Figure 1. Idealized Chip Formation Process (Turning)

The rubbing action or friction of the chip as it moves across the rake face of the tool also generates heat, although to a lesser degree than the chip formation process. Additional heat is generated as a result of the friction between the tool flank and the cut surface. Reducing friction in these cases results in a reduction of the heat generated. The traditional way of reducing friction is to apply a lubricant to the cut zone. In addition to lowering the friction at the chip-tool-workpiece interface, the addition of a lubricant affects the amount of heat generated during chip formation process. The amount of heat produced in the shear zone depends on the size of the shear angle. If the shear angle is small, then the plane in which deformation takes place extends a considerable distance ahead of the tool. The results is a short, thick chip and considerable heat. If the shear angle is large, the shear path is short and the result is a longer, thinner chip. This type of cut generates less heat. Application of a metal removal fluid reduces the friction between the chip and tool effectively increasing the shear angle and reducing heat. This effect is demonstrated in Figure 2.

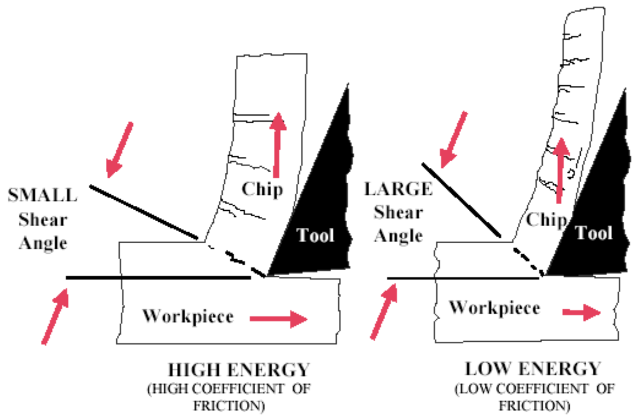

Figure 2. Effect of Metal Removal Fluid on Chip Formation

By reducing friction and removing heat from the chip-tool-workpiece interface, the operational lifetime of the cutting tool is prolonged. Depending upon what you are trying to accomplish, this means less cutting tool changes or the use of higher machining parameters (speeds and feeds) in the course of producing parts. Now be careful here, many times companies use tool lives as machining process performance indicators. Tool life is a function of the workpiece material, tool material, tool design, machining conditions, and chip-tool-workpiece temperature. Tools, just like metal removal fluids, are expensive. As such, there are many organizations out there who worry a great deal about tool life. Please remember the goal of your organization is to make money. Pushing parts out the door to your customers is the way to do this. You must balance the desire for long tool lives with the reality of the production schedules. Some organizations that demonstrate long tool lives may not be operating at their most productive level. In addition to their cooling and lubricating properties, metal removal fluids provide additional important functions that enhance overall part quality. The use of metal removal fluid chiller systems delivers metal removal fluid to the cut zone at extremely constant temperatures. This allows one to achieve and maintain very tight tolerances.

In some applications, the ability to remove chips from the cut zone is a primary function. Particularly in drilling applications, this prevents the chip from being re-cut as it travels up the drill flute and helps prevent packing of the drill flute. For this reason, high pressure metal removal fluid application systems are becoming more prevalent in drilling applications.

Perhaps one of the most critical roles that metal removal fluids play actually has little to do with machining. Depending upon the nature of the workpiece material and the final product, the presence of corrosion on machined surfaces is usually unacceptable. Ingredients present in metal removal fluids impart protection from atmospheric corrosion after the workpiece has been removed from the machine tool. Generally, this protection is short lived (less than 3 months) and for longer-term corrosion protection, the part most likely will require cleaning (removal of metal removal fluid) and application of a more traditional corrosion preventative.

Primarily, a cutting fluid must contribute in three ways to a machining process:

1 First, it must act as a lubricant. By reducing friction, it reduces the heat generated.

2 Because frictional heating cannot be completely eliminated - and often, not even substantially reduced - the cutting fluid must also act as an effective coolant.

3 Finally, it should act as an antiweld agent to counteract the tendency of the work material to weld the tool under heat and pressure.

Cutting fluids as a coolants

If a cutting fluid performs its lubricating function satisfactorily the problem of heat removal from the cutting tool, chip, and work is minimised. But, cooling still remains an important function. To perform this function effectively, a cutting fluid should possess high thermal conductivity so that maximum heat will be absorbed and removed per unit of fluid volume.

Cutting fluids as a lubricants

To perform satisfactorily as a lubricant, the cutting oil must maintain a strong protective film in that portion of the area between the tool face and the metal being cut where hydrodynamic conditions can exist. Such a film assists the chip in sliding readily over the tool. Besides reducing heat, proper lubrication lowers power requirements and reduces the rate of tool wear, particularly in machining tough, ductile metals.

WHAT ARE THE DIFFERENT TYPES OF CUTTING FLUIDS ?

- Soluble Oils
- Synthetic Oils
- Semi-Synthetic Oils
- Straight Cutting Oils

ECOLOGICAL ASPECTS OF CUTTING FLUIDS

Toxicity of the fluid components

A solid waste exhibits the characteristic of toxicity if, by using designated test methods, the liquid waste or extract from a representative sample contains any of the following contaminants at concentrations equal to or greater than the corresponding regulatory limit. A specific laboratory analytical procedure, identified as the Toxicity Characteristic Leaching Procedure (TCLP), is used to determine the toxicity of a waste. A waste that exhibits the characteristic of toxicity has a hazardous waste number that corresponds to the toxic contaminant(s) which cause it to be hazardous.

Flammability of the cutting fluid

Machining operations typically generate a significant amount of heat, which can cause cutting fluids to smoke and/or ignite. A fluid should have a high flashpoint to avoid problems associated with heat damage, the production of smoke, or fluid ignition.

Hazardous waste

There are many varieties of metalworking fluids and lubricants used in metal fabrication. Initially it is necessary to determine whether the product itself is classified as a hazardous waste. If the product itself is hazardous from a waste disposal standpoint, consider asking the vendor about nonhazardous alternatives.

Fluid disposal

Even with the best fluid management program, cutting fluid will not last indefinitely and will eventually require disposal. Environmental regulations are making disposal increasingly difficult. Generators are responsible for determining if a particular waste generated at their facility is hazardous or nonhazardous. The waste material must be tested using standard methods or the generator must have sufficient knowledge about the waste to assess whether it is a hazardous waste. Following a hazardous/nonhazardous determination for the waste, an appropriate disposal alternative may be selected. Spent cutting fluid that is determined to be hazardous must be disposed by a permitted hazardous waste management company in accordance with applicable federal and state regulations.

MINIMIZATION OF THE ECOLOGICAL IMPACTS OF CUTTING FLUIDS

Fluid selection

It is important to carefully select the metalworking fluid most suitable for the particular application to maximize its performance and fluid life. This will simplify operations, minimize contamination, and maximize purchasing power. To make informed choices of fluids, it is important to consider not only the fluids' performance characteristics, but other factors, such as:

- fluid life,
- waste treatability,
- cost of disposal,
- resistance to microbial attack,
- corrosion protection provided,
- type of residues left on the machine tools and workpieces,
- foaming characteristics
- part requirements (tolerance, finish, rust protection),
- machine requirements (lubrication, seals, paint, cleanliness, visibility of work area).

Keep the fluid from becoming a hazardous waste

Metalworking fluids may also become hazardous during use because they 'pick up' other waste materials. Therefore, the chemical component of the wastes reflect not only the *original makeup* of the process fluid, but also the operation and conditions of their use. In fact, many metalworking fluid wastes contain higher percentages of lubricating oil and suspended solids (dirt), and metal fines than they do metalworking fluid. If working with metals other than carbon steel, there is a possibilities that *heavy metals* (such as cadmium, copper, chromium, lead, mercury, nickel, silver, zinc) in the fluid waste will result in it being classified as hazardous waste. To find out whether the specific waste is hazardous, a sample must be sent to a certified lab for analysis using the TCLP (Toxicity Characteristic Leaching Procedure) test method.

Effective waste minimization

Effective waste minimization requires an investment of time and hard work. There is no magic wand or new technology that makes the selection and maintenance of metalworking fluids and lubricants easy, simple and free. Each company is different-in its particular needs and what works best for one may not be the best for another. Taking advantage of their own expertise and knowledge of local conditions, operators of each facility must determine whether a particular technology can be implemented economically. Most importantly, for a successful plan to be implemented, all personnel including owners, upper management, engineers, shop foremen, machine operators, etc. must buy in and become part of the team. Metalworking and fabrication companies of all sizes are making significant reductions in their operating costs and mandated environmental waste handling concerns by investing in an effective, organized Waste Reduction Program. These programs involve more than simple waste recycling; they cannot be bought off the shelf, ready-to-use from any vendor. Often, a Waste

Reduction Program becomes part of a company's overall Total Quality and Continuous Improvement efforts, improving and maintaining its competitive position in the marketplace.

FLUID MANAGEMENT PROGRAM

Fluid management has become an even more attractive pollution prevention alternative since increased automation in the metalworking industry allows costs to be kept at an acceptable level. These combined factors have resulted in the replacement of dispose and replenish routines with in-house fluid management programs.

A good fluid management program extends the useful life of metalworking fluids and has both economic and environmental advantages:

- Improves quality and repeatability
- Decreases costs of disposal for spent fluids
- Decreases purchase costs of fluids
- Less downtime for machine cleanouts and recharges
- Cleaner work environment and improved health conditions

The objectives of Fluid management program include:

- Educate fluid management personnel on processes that affect fluid performance and contribute to fluid failure;
- Identify corrective action procedures that can be utilized to maintain fluid performance and extend fluid life; and
- Provide management personnel with a useful reference for implementing an effective fluid management program.

The three components of a successful fluid management program are:

- Administration
- Fluid Monitoring and Maintenance
- Fluid Recycling

Facilities may realize a savings of 15 to 50 percent by implementing a thorough fluid management program. Payback for establishing a management program is often achieved within one or two years.

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