2.0 CUTTING FLUID CHARACTERISTICS

Cutting fluids are used in machine shops to improve the life and function of cutting tools. They are also a key factor in machine shop productivity and production of quality machined parts [1,2,3].

2.1 CUTTING FLUID SYSTEMS

Cutting fluid may be applied to a cutting tool/workpiece interface through manual, flood or mist application [3,4,5].

Manual application simply consists of an operator using a container, such as an oil can, to apply cutting fluid to the cutting tool/workpiece. Although this is the easiest and least costly method of fluid application, it has limited use in machining operations and is often hampered by inconsistencies in application.

Flood application delivers fluid to the cutting tool/workpiece interface by means of a pipe, hose or nozzle system. Fluid is directed under pressure to the tool/workpiece interface in a manner that produces maximum results. Pressure, direction and shape of the fluid stream must be regulated in order to achieve optimum performance.

Cutting fluids may also be atomized and blown onto the tool/workpiece interface via mist application. This application method requires adequate ventilation to protect the machine tool operator. The pressure and direction of the mist stream are also crucial to the success of the application.

Metalworking fluid used in flood or mist applications is typically stored and distributed utilizing an individual machine tool system or a central reservoir system [3]. Individual machine tools with internal cutting fluid systems consist of a sump for fluid storage, a pump, delivery piping, a spent fluid collection and return system, and a filter to remove contaminants. Coolant recirculates from the machine sump to the machine tool.

Centralized reservoir systems may contain hundreds of gallons of cutting fluid which is distributed to individual machine tools via a pump and piping system. Prior to fluid returning to the central reservoir, it is passed through a filtering system designed to remove contaminants such as metal chips and other particulates.

2.2 FUNCTIONS OF CUTTING FLUID

The primary function of cutting fluid is temperature control through cooling and lubrication [1]. Application of cutting fluid also improves the quality of the workpiece by continually removing metal fines and cuttings from the tool and cutting zone.

2.21 TEMPERATURE CONTROL

Laboratory tests have shown that heat produced during machining has a definite bearing on tool wear. Reducing cutting-tool temperature is important since a small reduction in temperature will greatly extend cutting tool life [3].

As cutting fluid is applied during machining operations, it removes heat by carrying it away from the cutting tool/workpiece interface [1,4]. This cooling effect prevents tools from exceeding their critical temperature range beyond which the tool softens and wears rapidly [8]. Fluids also lubricate the cutting tool/workpiece interface, minimizing the amount of heat generated by friction [1,4]. A fluid's cooling and lubrication properties are critical in decreasing tool wear and extending tool life. Cooling and lubrication are also important in achieving the desired size, finish and shape of the workpiece [2].

No one particular fluid has cooling and lubrication properties suitable for every metalworking application. Straight oils provide the best lubrication but poor cooling capacities. Water, on the other hand, is an effective cooling agent, removing heat 2.5 times more rapidly than oil [2]. Alone, water is a very poor lubricant and causes rusting. Soluble oils or chemicals that improve lubrication, prevent corrosion and provide other essential qualities must be added in order to transform water into a good metalworking fluid.

2.22 REMOVAL OF CUTTINGS AND PARTICULATES

A secondary function of metalworking fluid is to remove chips and metal fines from the tool/workpiece interface. To prevent a finished surface from becoming marred, cutting chips generated during machining operations must be continually flushed away from the cutting zone [1].

Application of cutting fluid also reduces the occurrence of built-up edge (BUE). BUE refers to metal particulates which adhere to the edge of a tool during machining of some metals. BUE formation causes increased friction and alters the geometry of the machine tool. This, in turn, affects workpiece quality, often resulting in a poor surface finish and inconsistencies in workpiece size [3]. Metalworking fluids decrease the occurrence of BUE by providing a chemical interface between the machine tool and workpiece.

2.3 FLUID PROPERTIES

In addition to providing a good machining environment, a cutting fluid should also function safely and effectively during machining operations.

2.31 CORROSION PROTECTION

Cutting fluids must offer some degree of corrosion protection. Freshly cut ferrous metals tend to rust rapidly since any protective coatings have been removed by the machining operation. A good metalworking fluid will inhibit rust formation to avoid damage to machine parts and the workpiece [3]. It will also impart a protective film on cutting chips to prevent their corrosion and the formation of difficult-to-manage chunks or clinkers [1].

To inhibit corrosion, a fluid must prevent metal, moisture and oxygen from coming together. Chemical metalworking fluids now contain additives which prevent corrosion through formation of invisible, nonporous films. Two types of invisible, nonporous films are produced by metalworking fluids to prevent corrosion from occurring. These include polar and passivating films [6]. Polar films consist of organic compounds (such as amines and fatty acids) which form a protective coating on a metal's surface, blocking chemical reactions. Passivating films are formed by inorganic compounds containing oxygen (such as borates, phosphates and silicates). These compounds react with the metal surface, producing a coating that inhibits corrosion.

2.32 STABILITY/RANCIDITY CONTROL

In the early days of the industrial revolution, lard oil was used as a cutting fluid. After a few days, lard oil would start to spoil and give off an offensive odor. This rancidity was caused by bacteria and other microscopic organisms that grew and multiplied within the oil. Modern metalworking fluids are susceptible to the same problem [1].

No matter how good the engineering qualities of a coolant, if it develops an offensive odor, it can cause problems for management. The toxicity of a fluid may also increase dramatically if it becomes rancid due to chemical decomposition, possibly causing the fluid to become a hazardous waste. Fluid rancidity shortens fluid life and may lead to increased costs and regulatory burdens associated with fluid disposal.

A good cutting fluid resists decomposition during its storage and use. Most cutting fluids are now formulated with bactericides and other additives to control microbial growth, enhance fluid performance and improve fluid stability.

2.33 TRANSPARENCY AND VISCOSITY

In some operations, fluid transparency or clarity may be a desired characteristic for a cutting fluid. Transparent fluids allow operators to see the workpiece more clearly during machining operations.

Viscosity is an important property with respect to fluid performance and maintenance. Lower viscosity fluids allow grit and dirt to settle out of suspension. Removal of these contaminants improves the quality of the fluid recirculating through the machining system. This can impact product quality, fluid life and machine shop productivity.

2.34 HEALTH AND SAFETY CONSIDERATIONS

Workers in machining operations are continually exposed to cutting fluid. A fluid must be relatively non-toxic, non-flammable and non-misting to minimize health and safety risks [5].

TOXICITY. Most metalworking fluids are not highly toxic. Toxicity problems associated with metalworking fluids are usually caused by the fluid becoming rancid, superconcentrated or contaminated [3]. The main routes of exposure for metalworking fluid include inhalation (via vapor, smoke or mist), ingestion and skin absorption [7]. Dermatitis and respiratory problems are the most frequent health problems of machine shop personnel.

Due to the variety of ingredients contained in metalworking fluids, it is often very difficult to anticipate whether the fluid will affect individuals constantly exposed to this material. The Material Safety Data Sheet (MSDS) for a metalworking fluid contains important health and safety information and should be reviewed as a first step in fluid selection [8].

FLAMMABILITY. 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.

MISTING. High speed metalworking operations such as grinding may atomize fluid, creating a fine mist which can be an inhalation hazard for machine tool operators [3]. Misting also creates a dirty work environment by coating equipment and the surrounding work area [1]. Non-misting fluids provide safer working conditions for the machine operator.