Waste Minimization and Wastewater Treatment of Metalworking Fluids

Definitions of Metalworking Fluids

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Definitions of Metalworking Fluids

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Universally accepted definitions and performance levels do not, as yet, exist in the metalworking fluid industry.

While "metalworking fluids" can be liquid, solid, or gaseous, practically all metalworking fluids in use today are liquid. A large variety of fluids are available to choose from depending on the specific requirements of the metalworking job. Some metalworking fluids are very general purpose while others are designed for specific applications. Metalworking fluids are considered to be metal removal fluids when they are used in operations designed to alter the metal work piece through formation and removal of chips. Metal removal operations include all forms of cutting and grinding. Metalworking fluids are metal forming fluids when they are used in operations designed to alter the shape of the metal work piece without the formation of a chip. Metal forming operations include all forms of stamping, forming, and extruding.

Metalworking fluids are basically divided into four classes: oil, soluble oil, semi-synthetic, and synthetic. The basis for this distinction is the amount of mineral oil contained in the concentrate of each product type. The oil products are used neat (not diluted with water) while the other three categories are all water soluble products. Each product type has distinct advantages and disadvantages.

Metal Removal/Forming Oils

A metal removal or forming oil is a fluid which may be an oil of petroleum, animal, marine, vegetable, or synthetic origin, used singly or in combination, or with additives. These products are not diluted with water for use. They are commonly referred to as cutting or grinding oils.

Extreme pressure (EP) additives, sulfur, chlorine, or phosphorous, are used to improve antiweld properties for heavy-duty applications. Chlorine is more reactive than sulfur and forms the EP lubricant at lower temperatures. Phosphorous is not as effective as either sulfur or chlorine and its use is less common. Generally, chlorine or sulfur are used by themselves or in various combinations, with chlorine preferred for cutting applications and sulfur for grinding.

Cutting oils are classified as active or inactive. An inactive oil will not darken a copper strip immersed in it for three hours at 100°C while an active oil will. Straight mineral oils containing sulfurized fatty acids are inactive oils. Active oils are sulfurized or sulfo-chlorinated mineral or fatty oils.

Straight mineral oil is used for light duty machining of ferrous or nonferrous metals. Its major function is as the base fluid for the other blends and additive oils.

Straight fatty oils are very limited in use because of their expense and frequent odor problems. They are used as wetting agents in blends with mineral oils and also to improve lubrication. Examples are palm oil, lard oil, and coconut oil.

A mineral fatty oil blend is a combination of one or more fatty oils blended into mineral oil. These products are nonstaining to ferrous and non-ferrous metals and are used where high surface finish and precision are required.

Sulfurized fatty mineral oil blends contain both fatty oils and sulfur and provide excellent lubricity. They stain less than sulfurized mineral oil since the sulfur is added as a sulfurized fat, in which strong chemical bonding keeps the sulfur from being released until the temperature reaches 265°C. They can be used on both ferrous and nonferrous metals. To increase the antiweld properties at lower temperatures and pressures, chlorine may be added, which will produce a heavy duty fluid for a wide range of applications.

Sulfurized mineral oils contain sulfur which is in the mineral oil. It reacts to form an iron sulfide film in the machining process which will reduce friction and built-up edge and provide antiweld properties. These oils are useful for machining tough, ductile metals. The reactivity of the sulfur makes them unsuitable for copper or copper alloys.

Sulfo-chlorinated mineral oil contains a combination of sulfur and chlorine additives to produce a product with exceptional antiweld properties over a wide temperature range. It is used for machining tough, low carbon steels. These straight oil products will generally provide the excellent lubrication needed in low clearance, high speed operations, especially where a high surface finish is required. They have good rust control. Good sump life is obtained because the bacteria that cause rancidity will not grow in oil unless it is contaminated with water. Since oil dissipates heat only half as fast as water, the straight oils will build up heat. The oil mist that occurs with their use will build up on parts, floors, and machines causing dirty and slippery conditions. In addition to the fire hazards associated with their use, other safety concerns may exist, especially if the machines are not properly shielded or if the work areas are not properly ventilated.

Soluble Oils

Soluble oil (or emulsifiable oil) is a combination of oil and emulsifiers for conventional products and may include other performance additives for premium products. These products are supplied as concentrates which are added to water at typical ratios of one part concentrate to five to 20

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parts water. The oil, generally 60% to 90% mineral oil in the concentrate, is made soluble by emulsifying agents, primarily sulfonates. The size of the emulsified particles is large enough to refract light and create a milky, opaque appearance. The EP additives sulfur, chlorine, or phosphorous may be added to form a soluble oil for very heavy-duty operations, including replacement of straight oils in some applications. Premium soluble oils may contain biocide packages, corrosion inhibitors, or other additives to enhance their performance.

Soluble oils are typically general purpose products, capable of being used in a wide variety of operations and on both ferrous and nonferrous metals. They offer good lubrication because of the amount of oil they contain and good cooling because of the heat dissipating effect of the water.

Soluble oils have some disadvantages. When mixed with hard water, some soluble oils may form a precipitate which can build up on parts, machines, and filters. In extreme cases, the emulsion may be split from this hard water. Depending on the operation and the machine set up, mist generated from a soluble oil can cause machines and work areas to become messy and slippery. Rust problems may occur with soluble oils if sufficient rust preventives are not incorporated in the formula. Since the water can support bacterial growth, rancidity problems and short sump life may occur if proper biocides are not present.

**Semi-Synthetic Fluids**

Semi-synthetic metalworking fluids have much lower mineral oil content than soluble oils, typically between 2% and 30% in the concentrate. Normally, when blended with water they form a translucent emulsion, but this can vary from transparent to opaque.

These fluids have also been called chemical emulsions or preformed chemical emulsions. This is because the concentrate does contain water and the emulsion or dispersion of oil will have already occurred during formulation. This is contrasted with a soluble oil where the emulsion does not form until the product concentrate is diluted with water for use.

Semi-synthetics have a high emulsifier content resulting in smaller oil globule formation and therefore a less opaque mix. These fluids also typically contain additives to provide wetting, corrosion control, cleaning, microbial control, and lubrication. Some may contain the EP additives sulfur, chlorine, or phosphorous to enhance lubrication. In general, semi-synthetics are intermediate between soluble oils and synthetics, offering some of the more desirable properties of each one.

Semi-synthetics generally have sufficient lubricity for moderate to heavy-duty applications. With better cooling and wetting properties than soluble oils, semi-synthetics make possible higher speeds and feed rates. These products also have better settling and cleaning properties than soluble oils, keeping machines cleaner. Good rancidity control contributes to a long and trouble free sump life. The reduced amount of oil contributes to less oil mist and less smoking, providing for a cleaner work environment.

Because they are emulsions, like soluble oils, semi-synthetics may also form a hard water scum if hard water is used in the mix. The cleaning action of these products may cause some to foam.

**Synthetic Fluids**

Synthetic metalworking fluids are those that contain no mineral oil. They can be classified into three types: simple, complex, and emulsifiable. When diluted with water (typically one to 10%) the simple and complex types form a transparent solution, while the emulsifiable type form an opaque emulsion.

The simple synthetic fluids basically consist of organic and inorganic salts dissolved in water. They function to offer corrosion control and cleaning action along with good heat removal. Simple synthetics are mainly used as grinding fluids for light duty operations.

The complex, in addition to the ingredients of the simple product, will also contain water soluble synthetic chemical lubricants making these products capable of moderate to heavy-duty type operations.

Simple and complex synthetics, because they are transparent solutions, enable the operator to see the work. They keep grinding wheels open and free-cutting, and produce considerably less mist than the other types of fluids. These synthetics usually have excellent microbial control, and their settling and cleaning properties help to extend fluid life. Their excellent cooling capability and the chemical lubrication of the complex type make high speeds and feeds, high production rates, and good size control possible. These synthetic fluids are also stable in hard water.

Because they do not contain oil, simple and complex synthetics do not offer physical lubrication. This may present a problem in certain heavy-duty cutting or grinding operations, or on certain machines where the metalworking fluid must also act as a lubricant. Some synthetic solutions may also foam under conditions of moderate to high agitation.

The newest type of synthetic fluid is the emulsifiable synthetic. It is a synthetic by definition because it does not contain mineral oil, but its opaque appearance and many of its performance properties are similar to a soluble oil. These products usually contain a combination of chemical and physical lubrication systems with the physical lubrication being derived from water soluble organic compounds such as esters, rather than mineral oil. They have the same advantages and disadvantages as other synthetic fluids except for the lack of transparency and the inclusion of a physical lubrication package. Emulsifiable synthetics make possible certain applications, especially aluminum machin-
ing, where previously it was difficult to achieve good results. This type of product is also used extensively in the metal stamping and drawing area.

Conclusion

These fluid definitions or classifications are based strictly on composition and mineral oil content. It is also possible to define metal removal and metal stamping fluids in terms of performance levels.

Performance may be based on certain industry standard tests or on a particular manufacturer's test and will define a fluid in such terms as lubrication, corrosion control, rancidity control, foaming tendencies, and oil emulsification. Each fluid manufacturer can provide a definition of type and performance level for its products.

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Cincinnati Milacron is a world leader in advanced manufacturing technologies (machinery, computer controls, software, cells and systems) for the metalworking and plastics processing industries; and in robotics, metrology, inspection, controls and information technologies for factory automation in general. The company is also a leading producer of precision grinding wheels and metalworking fluids. Cincinnati Milacron is a Regular Member of the Independent Lubricant Manufacturers Association.