International Journal of Research in Engineering and Innovation (IJREI)
journal home page: http://www.ijrei.com
ISSN (Online): 2456-6934

Review of cutting fluid properties and their fitness criteria for modern machining process

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Abstract

In present competitive manufacturing scenario the manufacturer has been obliged to make a minute observation to all aspect of production system. Nowadays main focus is being given to the manufacturing cost at no cost of quality as well as customers' demands. That's by machining process analysis has vital role in this aspect. In machining process heat generation affects shorter tool life, higher surface roughness and lowers the dimensional sensitiveness of work material. This result is more important when machining of difficult to cut materials, due to occurrence of higher heat. Lubricants have their own significance on tool life, properties of machined surface and surface accuracy. In advance manufacturing process, synthetic lubricants has become largest useable lubricants. In this paper the aim is to review the types and selection criteria of appropriate lubricants for respective material in modern machining process.

Keywords: lubricant additive, Economic aspect of lubricant, Isotherms, Hazardous. Gases and vapors lubrications

1. Introduction

In machining, metal cutting processes have an important place in the traditional production system. Cost effectiveness of all machining processes has been minutely observed. This is mainly affected selection of proper machining parameters like feed rate, cutting speed and depth of cut according to cutting tool and work piece material [1-2]. The selection of optimum machining parameters will result in longer tool life, better surface accuracy and higher material removal rate. Cutting Fluids are commonly applied to metal-cutting operations, mainly to cool the tool and work piece and provide lubrication [4]. In some cases, little benefit is obtained with a cutting fluid, but in most cases machining efficiency increases of 20–50%, and sometimes more. A cutting fluid is often called a coolant, and cooling is an important function at all cutting speeds. High temperatures are the main cause of tool wear [4-5]. An overheated work piece may warp. Coolants help to correct these conditions. Cutting fluids may serve to lubricate the chip sliding over the tool face. The evidence is that capillary action tends to draw the fluid in through the natural grinding scratches on the face of the tool. Lubrication reduces friction forces acting on the tool, improving tool life and decreasing power consumption [6]. Cutting fluids have a dual role; cooling and lubrication. In high-speed cutting operations where the tool remains buried in the cut most of the time, such as in turning, the function of the fluid is primarily one of cooling [7]. In low-speed operations involving intermittent cutting, such as in broaching or tapping, lubrication is important. Both water-base and oil base lubricants are used, the former are generally better coolants while the latter are better lubricants. There are many secondary considerations associated with cutting fluids such as chip disposal, corrosion prevention, health and safety considerations, etc. It is unlikely that anything but a vapor can penetrate the interface between chip and tool during a continuous cutting operation [8]. This is due to perfect contact between chip and tool and the normally high-speed motion of the chip counter to fluid penetration. When a cutting fluid is introduced between the tool and chip, friction is reduced, the shear angle increases, the chip becomes thinner, the power requirement is reduced, and less heat is generated. Also, the

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https://doi.org/10.36037/IJREI.2019.3602

built-up edge disappears, the finish smooth out, and size control improves. The nascent metal exposed under the high temperature and pressure conditions reacts with chemicals in the cutting fluid to form a low shear strength solid between the chip and the tool [8-9]. The chip slides freely up the tool face, tools last much longer, speed sand feeds can be stepped up, and more work can be done with each tool. The cooling and lubricating mechanisms are dependent on the job: slow-speed, slow-feed operations need more lubrication while high-speed, high-feed operations need more cooling [10].

2. Types of Cutting Fluids

Cutting oil contains mineral oil, fatty oil, or a combination of these. Mineral oils are by products petroleum; fatty oils sources are animal or vegetable. Extreme pressure (EP) sulfur, chlorine, or phosphorus additives are employed to improve anti sticking properties for heavy-duty applications [11]. Sulfur forms a better lubricant, but chlorine is more reactive than sulfur and breaks down to form the Extreme pressure lubricant at lower temperatures. Phosphorus is not as effective as either sulfur or chlorine and its use is less common. Cutting oils are often classified as active or inactive; Inactive oils are straight mineral oils, containing sulfurized fatty oils. Active oils are sulfurized or sulfochlorinated mineral or fatty oils [12].

2.1 Straight mineral oil

Used for light-duty machining of ferrous or nonferrous metals, it is a base fluid for the blends and additive oils listed below.

2.2 Straight fatty oils

Very limited use because of their expense and frequent odor problems. It is used mainly as in blends with mineral oils. Palm oil, lard oil, and coconut oil are the most popular.

2.3 Mineral fatty oil blend

Combinations of one or more fatty oils, blended into mineral oil. The fatty oils act as wetting agents and improve the lubrication of the mineral oil. These products are non-staining to ferrous and nonferrous metals and are used where high surface finish and precision are required, especially automatic screw machines [14].

2.4 Sulfurized fatty mineral oil blend

These oils, containing both fatty oil and sulfur additives, have 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 readily released until the temperature reaches 265°C. They can be used on both ferrous and nonferrous metals. Chlorine may also be added to increase the anti-sticking properties at low temperatures and pressures, thus producing a heavy-duty fluid for a wide range of operations.

2.5 Sulfurized mineral oil

Sulfur is dissolved in the mineral oil and forms an iron sulfide film in the machining process. This reduces friction and built-up edge, and provides anti weld properties. These oils are useful for machining tough, ductile metals. Reactivity of the sulfur makes them unsuitable for copper or copper alloys.

2.6 Sulfo-chlorinated mineral oil

Combination of sulfur and chlorine additives produces products with exceptional anti weld properties over a wide temperature range. They are used for machining (especially threading) tough, low-carbon steels. Fatty oils added to this type of product produce cutting oil for a wide range of heavy-duty and slow-speed operations.

2.7 Emulsified Oils (Soluble Oils)

These mixtures of mineral oil and emulsifiers are supplied as concentrates which are added to water at the ratio of 1 part concentrate to 5 to 20 parts water. The oil is made soluble by emulsifying agents, primarily sulfonates [15]. The emulsified particles range in size from 200 to 80 μm, large enough to reflect light and create a milky, opaque appearance when mixed with water. Premium grades may contain bactericides and corrosion inhibitors. Addition of fatty oils, fatty acids, or esters produces a super fatted emulsion for heavy-duty use on both ferrous and nonferrous metals. Sulfur, chlorine, or phosphorous, in addition to the fat, form an extreme pressure emulsion for very heavy-duty operations, including replacement of straight cutting oil in some applications[16].

3. Cutting Fluid Selection

Type of job material and performance properties must be considered in selecting a cutting fluid.

3.1 Type of Shop

Production program is the scale of selection: single item, batch, or mass production, which machining processes are used, High-production shops, with many machines doing the same operation, can use a single type cutting fluid designed to meet specific requirements [17]. Hardware type of production equipment is also considerable. The machine tools supplied with cutting fluid individually or from a central system some time particular cutting fluids recommended by the manufacturer of the machines. If different materials and types of machining processes are involved in the production process, then a universal cutting fluid might be a better choice than a number of different products, even if they would individually give better performance.

3.2 Type of Machine

Many machines required cutting oil to serve both as the cutting fluid and as the slide way lubricant. Modern machines, however, are designed for use of water based fluids. They have good lubrication systems, effective seals around the spindles, and wipers on the slide ways. With the exception of some six-spindle automatics and some gear cutting equipment.

3.3 Type of Operation

Threading, reaming, tapping, and broaching are perhaps the most difficult machining operations, because of chip clotting, and generally require a cutting fluid that reduces friction. Turning, drilling, boring, and similar less difficult operations can be performed with products having low to moderate friction reducing properties. Some grinding can be performed with cutting fluids that provide little friction reduction. Others, such as form grinding, require a heavy-duty fluid. If performed regularly, the most critical operation in a shop may dictate the cutting fluid selection.

4. Cutting fluid controls

Control of the system, which includes maintenance of the mechanical components as well as the cutting fluid, is equally important as cutting fluid selection for increasing the life of the fluid [4]. The problems that beset cutting fluids in central system applications are the same as those in individual machines, only the magnitude is greater. A program to accomplish this control should include the following basic steps to obtain long fluid life and avoid problems [18-19].

- Assign the responsibility of control to one individual
- Clean the system thoroughly before charging with a fresh mix
- Maintain the cutting fluid mix concentration at the recommended dilution
- Keep the cutting fluid free of chips and grit
- Use water that has a low dissolved solids content
- Aerate the cutting fluid
- Provide good chip flushing at the machines and in the trenches
- Employ good housekeeping practices.

5. Cutting Fluid Application

Improved tool life, better surface finish, lower power consumption, greater accuracy, and efficient chip flushing can be achieved when clean fluid floods the cutting zone. Generally, a large volume of cutting fluid at low pressure is most effective. Higher fluid pressures are required for grinding because of air currents generated by the grinding wheel.

5.1 Manual Application

Manual application consists of brushing, dripping, or squirting cutting fluid on the cutting area. This method is occasionally recommended except in conjunction with flood application systems. For example, tapping compound is often manually applied on a tapping or threading operation where extra friction-reducing chemicals are needed to provide the tool life and finish required.

5.2 Mist Application

Cutting fluid is sometimes applied as a mist generated by pumping the cutting fluid through a special nozzle where it mixes with air. Mist application has found its greatest use where, because of part size or configuration, cutting fluid could not be rechanneled to the reservoir. Mist is used in operations such as high-speed sawing of extruded aluminum window and door frames where the machine is not equipped with a cutting fluid re-circulating system. Mist application also makes the use of fluids practical with portable tools.

5.3 Flood Application

Flooding is the most common application method [1-2]. In turning and facing, the cutting fluid is directed to the area where the chip is formed using two nozzles; one above and one below the tool. In slab milling the cutting fluid is directed to both sides of the cutter, again using two nozzles. One nozzle insures that the cutting fluid reaches the cutting zone;the other washes out the chips. In the case of face milling, a ring-type distributor can direct as many streams of fluid as needed to flood each tooth of the cutter. For drilling, reaming,

5.4 High Pressure Application

Application of cutting fluid to grinding operations requires the part to be cooled, the grinding wheel kept clean, and friction reduced as the chip is formed. The heat produced in grinding is caused by friction; at each grain interface temperatures normally reach 950 to 1400°C [20]. Grinding dry, or otherwise failing to reduce heat, can affect wheel wear, grinding accuracy, and the physical characteristics of a part. To control grinding heat, the cutting fluid must penetrate directly to the cutting zone through the high-pressure air bubble surrounding the wheel.

5.5 Gases and vapors lubrications

Cutting oils and water miscible types of cutting fluids are the most widely used; Compressed air, inert gases like carbon dioxide, Freon, and Nitrogen are sometimes used. A vortex tube is used to apply gaseous lubricants or coolants. Using this tube, it is possible to apply the gases at a very low temperature and under medium pressure thereby facilitating a higher gas density and cooling and lubrication capability. Cutting using sub-zero cold gas is known as cryogenic cutting. The gas stream also helps to blow away chips from the cutting area. The further advantage of a gaseous or vapor phase cutting fluid is that the constituents are of a far finer nature than liquids or solids, and due to the way of application, namely jet application, have far greater kinetic energy, and therefore have a greater penetrative capability. Molecular exchange is much slower when flood lubrication is used. Any adhered film is static and can be penetrated by the cutting fluid when jet type application is used. This promotes convective cooling and adds capacity for evaporative cooling.

5.6 Paste and Solid Lubricants

Waxes, pastes, soaps, graphite and molybdenum disulphide are examples falling into this category. These are generally applied directly to the work piece or tool or in some cases impregnated directly into the tool, for example the grinding wheel of a grinder. One example of a paste lubricant is lard. Many experienced journeymen recommend lard for tapping.

6. Cutting Fluid Maintenance

Corrective measures may have to be taken as a result of test findings and a variety of products are available on the market for this purpose. These include

- Topping upto correct the concentration foam agents
- To prevent foaming system cleaner - for initial disinfection before filling up with new cutting fluid bactericide
- To improve biological stability if the cutting fluid is used properly.
- It should not be necessary to add bactericide as a corrective measure. However, in the majority of cases some bactericide will have to be used. Nevertheless, bactericide should be used sparingly since, as already mentioned, excessive amounts can lead to a sudden rise in alkalinity and may cause skin irritation.

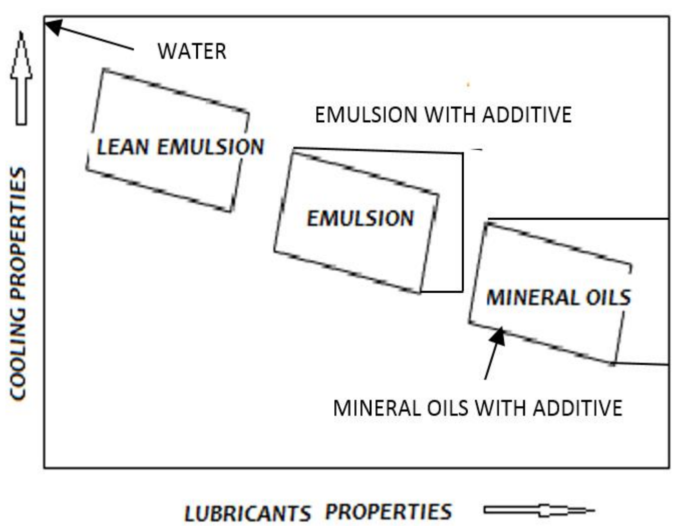

Figure 1: Lubricating and cooling properties of metal working Fluids

7. Gas Solubility in lubricants

Gases Solubility in lubricants is a physical property that in turn affects the properties of lubricant such as viscosity, foaming, bulk modulus, heat transfer, oxidation, and boundary lubrication. In many cases, gas is trapped at low pressures and then dissolved in the high-pressure portion of lubrication and hydraulic systems. As the pressure is again reduced to that in the reservoir or sump, the gas comes out of solution to produce foam or just evolve in gas bubbles. The oxygen of air, in the case of air, can also react with the lubricant as the temperature in bearings or hot portions of the system reaches the threshold of the oxidation reaction.

7.1 Health Hazards

Measures to protect the health of operators are also an important part of cutting fluid maintenance. Cutting fluid manufacturers normally offer proof that their product has no harmful dermatological or physiological effects - usually in the form of a skin health certificate, which is separate from the safety sheet [21]. Long-term exposure under certain climatic conditions will inevitably lead to undesired changes in skin condition - irritation for instance - and even water causes changes in the skin condition after prolonged contact. The main health protection measures to be observed are as follows: as far as possible avoid direct contact with cutting fluids in any form whatsoever use cosmetic skincare products - skin creams, barrier creams, mild soaps, etc., to minimize the danger of skin damage monitor cutting fluids continuously during use[22]. in order to prevent possible causes of skin irritation arising in the first place see that personnel are repeatedly informed about the correct use and handling of cutting fluids Information about possible dangers to health and the appropriate counter measures are freely available from a variety of sources, from trades unions, industry associations, and the coolant manufacturers themselves. In specific cases, a doctor - such as the work's doctor, when appropriate - can ask the manufacturer for information about the composition of a product [23].

8. Economic Aspects of cutting fluid

The cutting fluid forms part of the production process and so its economic performance can only be judged in relation to its overall effect on the process as a whole. When seen in this light, the purchase price plays only a minor role [24]. Of much more importance are the costs which occur if the cutting fluid does not do its intended job correctly and in every aspect. The purchase price is therefore not the only economic criterion. A product which is initially more expensive but offers better performance and a longer life can turn out to be less expensive in the long run than a cheaper variety. Furthermore, the cutting fluid also has an effect on tool wear and surface finish, which have to be taken into consideration as cost factors. In addition to the directly measurable costs, the constant product quality and the service provided by the cutting fluid manufacturer also play a significant role in its economic performance. In summary, it can be said that cutting fluids play a vital role in the metal cutting operation and as much care over their selection is required as would be made when purchasing a machine tool. After all, this is a resource which will, at best, improve productivity and quality greatly and, at worst, cause poor cutting tool performance, part rejection and real damage to the machine tool and any work holding equipment [24].

9. Conclusions

For modern metal cutting processes in general to achieve various benefits such as longer tool life, high quality surface finish and better dimensional accuracy. These results also provide higher cutting speeds, feeding rates and cutting depth. The productivity of the manufacturing process will be much higher with a range of selection of higher manufacturing parameters. Material removal rates will be increased. However, environmental legislation has forced the elimination or reduction of the use of liquids in automation processes since the early 1970s. Moreover, the application of cutting fluids has negative effects on workers' health New approaches for reducing cutting fluids application in machining processes have been examined and promising results such as dry machining, advancements on cutting tool materials have been reported. Moreover new coating technologies for various cutting tools have provided important advantages to reduce cutting fluid application in machining operation.

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***Cite this article as**:* Md Mushid, Vijay Mittal, Musheer Ahmed, Anil Kumar, Review of cutting fluid properties and their fitness criteria for modern machining process, International Journal of Research in Engineering and Innovation Vol-3, Issue-6 (2019), 359-363.
http://doi.org/10.36037/IJREI.2019.3602