A REVIEW ON SELECTION OF CUTTING FLUIDS

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ABSTRACT

In this paper, during machining process heat generated and effects tool life shorter, higher surface roughness and lower the dimensional sensitiveness of work material. Different methods have been reported to protect cutting tool from the generated heat during machining operations. The selection of coated cutting tools are an expensive alternative and generally it is a suitable approach for machining some materials such as titanium alloys, heat resistance alloys etc. Another alternative is to apply cutting fluids in machining operation. They are used to provide lubrication and cooling effects between cutting tool and workpiece and cutting tool and chip during machining operation. Hence the influence of generated heat on cutting tool would be prevented. The selection of cutting fluids should be carefully carried out to obtain optimum result in machining processes. The selection criteria of cutting fluids for various material machining processes have been determined according to cutting tool materials.

***Keywords*:** Machining, Tool materials, Cutting fluids, Engineering materials.

INTRODUCTION

During machining process, friction between workpiece-cutting tool and cutting tool- chip interfaces cause high temperature on cutting tool. The effect of this generated heat decreases tool life, increases surface roughness and decreases the dimensional sensitiveness of work material. This case is more important when machining of difficult-to- cut materials, when more heat would be observed [1]. Various methods have been reported to protect cutting tool from the generated heat. Choosing coated cutting tools are an expensive alternative and generally it is a suitable approach for machining some materials such as titanium alloys, heat resistance alloys etc.

During metal cutting heat generated as a result of work done .Heat is carried away from the tool and work by means of cutting fluids, which at the same time reduced the friction between the tool and chip and between tool and work and facilitates the chip formation. Cutting fluids usually in the form of a liquid are to the formation zone to improve the cutting condition. The application of cutting fluids is another alternative to obtain higher material removal rates. Cutting fluids have been used widespread in all machining processes. However, because of their damaging influences on the environment, their applications have been limited in machining processes [2-6].

Cost effectiveness of all machining processes has been eagerly investigated. This is mainly affected selection of suitable machining parameters like cutting speed, feed rate and depth of cut according to cutting tool and workpiece material. The selection of optimum machining parameters will result in longer tool life, better surface finish and higher material removal rate.

Many types of cutting fluids namely, straight oils, soluble oils, synthetic and semi synthetic are widely used in metal cutting processes. Bio-based cutting fluids have the potential to reduce the waste treatment costs due to their inherently higher biodegradability and may reduce the occupational health risks associated with petroleum-oil-based cutting fluids since they have lower toxicity. The output is a healthier and cleaner in the work environment, with less mist in the air.

Functions of cutting fluids

1. To prevent the tool from overheating i.e. So that no temperature is reached where the tool's hardness and resistance to abrasion are reduced, thus decreasing the tool life.
2. To keep the work cool, preventing machining those results in inaccurate final dimensions.
3. To reduce power consumption, wear on the tool, and the generation of heat by affecting the cutting process. This investigation wishes to establish a relationship between the surface chemistry of the lubricants involved and how they can accomplish reducing the contact length on the rake face of the tool where most of the heat during cutting is produced.
4. To provide a good surface finish on the work.
5. To aid in providing a satisfactory chip formation (related to contact length)
6. To wash away the chips/clear the swarf from the cutting area.
7. To prevent the corrosion of the work, the tool and the machine.

The desirable properties of cutting fluid in general

1. High thermal conductivity for cooling.
2. Good lubricating qualities.
3. High flash point should not entail a fire hazard.
4. Must not produce a gummy or solid precipitate at ordinary working temperatures.
5. Be stable against oxidation.
6. Must not promote corrosion or dislocation of the work material.

7. Must afford some corrosion protection to newly formed surfaces.
8. The components of the lubricant must not become rancid easily.
9. No unpleasant odor must develop from continued use.
10. Must not cause skin irritation or contamination.
11. A viscosity that will permit free flow from the work and dripping from the chips.

Types cutting fluids

The cutting fluids applied in machining processes basically have three characteristics [5, 10, and 14]. These are:

- Cooling effect
- Lubrication effect

Taking away formed chip from the cutting zone. The cooling effect of cutting fluids is the most important parameter. It is necessary to decrease the effects of temperature on cutting tool and machined workpiece. Therefore, a longer tool life will be obtained due to less tool wear and the dimensional accuracy of machined workpiece will be improved [5,10,14].

The lubrication effect will cause easy chip flow on the rake face of cutting tool because of low friction coefficient. This would also result in the increased by the chips. Moreover, the influence of lubrication would cause less built-up edge when machining some materials such as aluminium and its alloys. As a result, better surface roughness would be observed by using cutting fluids in machining processes [5, 10, 14].

It is also necessary to take the formed chip away quickly from cutting tool and machined workpiece surface. Hence the effect of the formed chip on the machined surface would be eliminated causing poor surface finish. Moreover part of the generated heat will be taken away by transferring formed chip [10, 14].The following factors should be considered when selecting a fluid [1, 2, 8, and 9]:

1. Cost and life expectancy
2. Fluid compatibility with work materials and machine components
3. Speed, feed and depth of the cutting operation
4. Type, hardness and microstructure of the metal being machined
5. Ease of fluid maintenance and quality control
6. Ability to separate fluid from the work and cuttings
7. The product’s applicable temperature operating range
8. Optimal concentration and pH ranges
9. Storage practices
10. Ease of fluid recycling or disposal

The most common metalworking fluids used today belong to one of two categories based on their oil content [2, 8]:

Oil-Based Fluids - including straight oils, soluble oils and ag-based oils

Chemical Fluids - including synthetics and semisynthetics

Fluids vary in suitability for metalworking operations. For example, petroleum-based cutting oils are frequently used for drilling and tapping operations due to their excellent lubricity while water-miscible fluids provide the cooling properties required for most turning and grinding operations. The following provides a description of the advantages, disadvantages and applications of each metalworking fluid category.

1. Oil-based cutting fluids

1. STRAIGHT OILS (100% petroleum oil)

Straight oils, so called because they do not contain water, are basically petroleum, mineral, or ag-based oils. They may have additives designed to improve specific properties [25, 27]. Generally additives are not required for the easiest tasks such as light-duty machining of ferrous and nonferrous metals [32, 35]. For more severe applications, straight oils may contain wetting agents (typically up to 20% fatty oils) and extreme pressure (EP) additives such as sulfur, chlorine, or phosphorus compounds. These additives improve the oil's wettability; that is, the ability of the oil to coat the cutting tool, workpiece and metal fines [36]. They also enhance lubrication, improve the oil's ability to handle large amounts of metal fines, and help guard against microscopic welding in heavy duty machining. For extreme conditions, additives (primarily with chlorine and sulfurized fatty oils) may exceed 20%. These additives strongly enhance the antiwelding properties of the product [35].

Advantages: The major advantage of straight oils is the excellent lubricity or "cushioning" effect they provide between the workpiece and cutting tool [27]. This is particularly useful for low speed, low clearance operations requiring high quality surface finishes [32,35]. Although their cost is high, they provide the longest tool life for a number of applications. Highly compounded straight oils are still preferred for severe cutting operations such as crush grinding, severe broaching and tapping, deep-hole drilling, and for the more difficult-to-cut metals such as certain stainless steels and super alloys. They are also the fluid of choice for most honing operations due to their high lubricating qualities [36]. Straight oils offer good rust protection, extended sump life, easy maintenance, and are less likely to cause problems if misused. They also resist rancidity, since bacteria cannot thrive unless water contaminates the oil [32].

Disadvantages of straight oils include poor heat dissipating properties and increased fire risk [32,35]. They may also create a mist or smoke those results in an unsafe work environment for the machine operator, particularly when machines have inadequate shielding or when shops have poor ventilation systems. Straight oils are usually limited to low temperature, low-speed operations [25]. The oily film left on the workpiece makes cleaning more difficult, often requiring the use of cleaning solvents. Straight oil products of different viscosities are available for each duty class. Viscosity can be thought of as a lubricant factor--the higher the oil's viscosity, the greater its lubricity. Highly viscous fluids tend to cling to the workpiece and tool. This causes increased cutting fluid loss by dragout and necessitates lengthier, more costly cleanup procedures. It can be more efficient to choose low-viscosity oil that has been compounded to provide the same lubricity as a highly viscous one.

2. SOLUBLE OILS (60-90% petroleum oil)

Soluble oils (also referred to as emulsions, emulsifiable oils or water-soluble oils) are generally comprised of 60-90 percent petroleum or mineral oil, emulsifiers and other additives [25, 32, and 37]. A concentrate is mixed with water to form the metalworking fluid. When mixed, emulsifiers (a soap-like material) cause the oil to disperse in water forming a stable "oil-in-water" emulsion [26, 36]. They also cause the oils to cling to the workpiece during machining. Emulsifier particles refract light, giving the fluid a milky, opaque appearance.

Advantages Soluble oils offer improved cooling capabilities and good lubrication due to the blending of oil and water [36]. They also tend to leave a protective oil film on moving components of machine tools and resist emulsification of greases and slideway oils [26].

Soluble oils are a general purpose product suitable for light and medium duty operations involving a variety of ferrous and nonferrous applications. Although they do not match the lubricity offered by straight oils, wetting agents and EP additives (such as chlorine, phosphorus or sulfur compounds) can extend their machining application range to include heavy-duty operations. Most cutting operations handled by straight oils (such as broaching, trepanning, and tapping) may be accomplished using heavy-duty soluble oils.

Disadvantages the presence of water makes soluble oils more susceptible to rust control problems, bacterial growth and rancidity, tramp oil contamination, and evaporation losses. Soluble oils are usually formulated with additives to provide additional corrosion protection and resistance to microbial degradation. Maintenance costs to retain the desired characteristics of soluble oil are relatively high.

Other disadvantages of soluble oils include the following: When mixed with hard water, soluble oils tend to form precipitates on parts, machines and filters [32, 35]; Due to their high oil content, they may be the most difficult of the water-miscible fluids to clean from the workpiece. As a result of these disadvantages, soluble oils have been replaced in most operations with chemical cutting fluids. Misting of soluble oils may produce a dirty and unsafe work environment, through slippery surfaces and inhalation hazards.

2. Chemical cutting fluids

Chemical cutting fluids, called synthetic or semisynthetic fluids, are stable, preformed emulsions which contain very little oil and mix easily with water. Chemical cutting fluids rely on chemical agents for lubrication and friction reduction [32].These additives also improve wettability. At temperatures above approximately 390^{o}F (200^{o}C),these additives become ineffective and EP lubricant additives (chlorine, phosphorus and sulfur compounds) are utilized. These compounds react with freshly-machined metal to form chemical layers which act as a solid lubricant and guard against welding during heavy-duty machining operations. Fluids containing EP lubricants significantly reduce the heat generated during cutting and grinding operations.

1. SYNTHETICS (0% petroleum oil)

Synthetic fluids contain no petroleum or mineral oil [26, 35]. Generally consist of chemical lubricants and rust inhibitors dissolved in water. Like soluble oils, synthetics are provided as a concentrate which is mixed with water to form the metalworking fluid. These fluids are designed for high cooling capacity, lubricity, corrosion prevention, and easy maintenance. Due to their higher cooling capacity, synthetics tend to be preferred for high-heat, high-velocity turning operations such as surface grinding. They are also desirable when clarity or low foam characteristics are required. Heavy-duty synthetics, introduced during the last few years, are now capable of handling most machining operations. Synthetic fluids can be further classified as simple, complex or emulsifiable synthetics based on their composition [32,35]. Simple synthetic concentrates (also referred to as true solutions) are primarily used for light duty grinding operations [26]. Complex synthetics contain synthetic lubricants and may be used for moderate to heavy duty machining operations. Machining may also be performed at higher speeds and feeds when using complex synthetics. Both simple and complex synthetics form transparent solutions when mixed in a coolant sump, allowing machine operators to see the workpiece. Emulsifiable synthetics contain additional compounds to create lubrication properties similar to soluble oils, allowing these fluids to double as a lubricant and coolant during heavy-duty machining applications. Due to their wettability, good cooling and lubricity, emulsifiable synthetics are capable of handling heavy-duty grinding and cutting operations on tough, difficult-to-machine and high temperature alloys [26]. The appearance of emulsifiable synthetic fluids ranges from translucent to opaque.

1. Chemical agents found in most synthetic fluids include:
2. Amines and nitrites for rust prevention
3. Nitrates for nitrite stabilization
4. Phosphates and borates for water softening
5. Soaps and wetting agents for lubrication
6. Phosphorus, chlorine, and sulfur compounds for chemical lubrication
7. Glycols to act as blending agents
8. Biocides to control bacterial growth

Advantages: Synthetic fluids have the following qualities which contribute to superior service life [32, 47]

1. Excellent microbial control and resistance to rancidity for long periods of time.
2. Nonflammable, nonsmoking and relatively nontoxic.
3. Good corrosion control.
4. Superior cooling qualities.
5. Greater stability when mixed with hard water.

6. Reduced misting problems
7. Reduced foaming problems.

Synthetics are easily separated from the workpiece and chips, allowing for easy cleaning and handling of these materials. In addition, since the amount of fluid clinging to the workpiece and chips is reduced, less makeup fluid is needed to replace coolant lost to drag-out.

Good settling properties allow fine particulates to readily drop out of suspension, preventing them from recirculating and clogging the machine-cooling system. Overall, synthetics are easier to maintain due to their cleanliness, they offer long service life if properly maintained and can be used for a variety of machining operations.

Disadvantages although synthetics are less susceptible to problems associated with oil-based fluids, moderate to high agitation conditions may still cause them to foam or generate fine mists [25]. A number of health and safety concerns, such as misting and dermatitis, also exist with the use of synthetics in the shop [32]. Ingredients added to enhance the lubricity and wettability of emulsifiable synthetics may increase the tendency of these fluids to emulsify tramp oil, foam and leave semi-crystalline to gummy residues on machine systems (particularly when mixed with hard water) [26].

Synthetic fluids are easily contaminated by other machine fluids such as lubricating oils and need to be monitored and maintained to be used effectively [25,36].

2. SEMISYNTHETICS (2-30% petroleum oil)

As the name implies, semisynthetics (also referred to as semi-chemical fluids) are essentially a hybrid of soluble oils and synthetics. They contain small dispersions of mineral oil, typically 2 to 30 percent, in a water-dilutable concentrate [25,32,38]. The remaining portion of a semi-synthetic concentrate consists mainly of emulsifiers and water. Wetting agents, corrosion inhibitors and biocide additives are also present. Semisynthetics are often referred to as chemical emulsions or preformed chemical emulsions since the concentrate already contains water and the emulsification of oil and water occurs during its production.

The high emulsifier content of semisynthetics tends to keep suspended oil globules small in size, decreasing the amount of light refracted by the fluid. Semisynthetics are normally translucent but can vary from almost transparent (having only a slight haze) to opaque [32, 35]. Most semisynthetics are also heat sensitive. Oil molecules in semisynthetics tend to gather around the cutting tool and provide more lubricity. As the solution cools, the molecules redisperse.

Advantages like synthetics, semisynthetics are suitable for use in a wide range of machining applications and are substantially easier to maintain than soluble oils. They provide good lubricity for moderate to heavy duty applications. They also have better cooling and wetting properties than soluble oils, allowing users to cut at higher speeds and faster feed rates [32]. Their viscosity is also less than that of soluble oil, providing better settling and cleaning properties. Semisynthetics provide better control over rancidity and bacterial growth, generate less smoke and oil mist (because they contain less oil than straight or soluble oils), have greater longevity, and good corrosion protection.

Disadvantages Water hardness affects the stability of semisynthetics and may result in the formation of hard water deposits. Semisynthetics also foam easily because of their cleaning additives and generally offer less lubrication than soluble oils.

3. Cutting Fluid Types Advantages Vs Disadvantages

1. Straight Oils

Advantages - Excellent lubricity; good rust protection; good sump life; easy maintenance; rancid resistant

Disadvantages - Poor heat dissipation; increased risk of fire, smoking and misting; oily film on workpiece; limited to low-speed, severe cutting operations

2. Soluble Oil

Advantages- Good lubrication; improved cooling capabilities; good rust protection; general purpose product for light to heavy duty operations

Disadvantages - More susceptible to rust problems, bacterial growth, tramp oil contamination and evaporation losses; increased maintenance costs; May form precipitates on machine; misting; oily film on workpiece

3. Synthetics

Advantages - Excellent microbial control and resistance to rancidity; relatively nontoxic; transparent; nonflammable/nonsmoking; good corrosion control; superior cooling qualities; reduced misting/foaming; easily separated from workpiece/chips; good settling/cleaning properties; easy maintenance; long service life; used for a wide range of machining applications

Disadvantages - Reduced lubrication; may cause misting, foaming and dermatitis; may emulsify tramp oil; may form residues; easily contaminated by other machine fluids

4. Semisynthetics

Advantages - Good microbial control and resistance to rancidity; relatively nontoxic; nonflammable/ nonsmoking; good corrosion control; good cooling and lubrication; reduced misting/foaming; easily separated from workpiece/chips; good settling/cleaning properties; easy maintenance; long service life; used for a wide range of machining applications

Disadvantages - Water hardness affects stability; may cause misting, foaming and dermatitis; may emulsify tramp oil; may form residues; easily contaminated by other machine fluids.

Methods of application

Manual application

Application of a fluid from a can manually by the operator. It is not acceptable even in job-shop situations except for tapping and some other operations where cutting speeds are very low and friction is a problem. In this case, cutting fluids are used as lubricants.

Flooding

In flooding, a steady stream of fluid is directed at the chip or tool-workpiece interface. Most machine tools are equipped with a recirculating system that incorporates filters for cleaning of cutting fluids. Cutting fluids are applied to the chip although better cooling is obtained by applying it to the flank face under pressure:

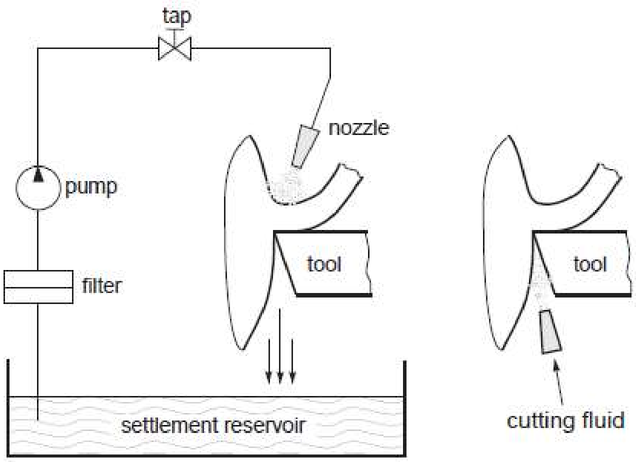

Fig 1. Cutting Fluid Application,(left) rake face flooding by means of recirculating sysytem,(right) flank face application of the cutting fluid.

Coolant-Fed Tooling

Some tools, especially drills for deep drilling, are provided with axial holes through the body of the tool so that the cutting fluid can be pumped directly to the tool cutting edge.

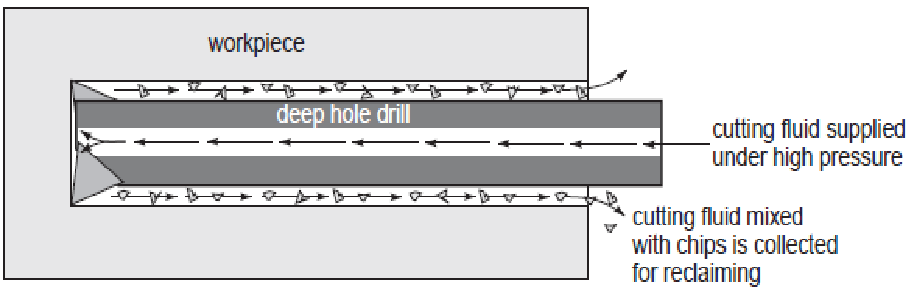

Fig 2. Internal cutting fluid application in deep hole drilling

Mist applications

Fluid droplets suspended in air provide effective cooling by evaporation of the fluid. Mist application in general is not as effective as flooding, but can deliver cutting fluid to inaccessible areas that cannot be reached by conventional flooding. Mist application requires a high pressure and impinged at high speed through the nozzle at the cutting zone. The mist application system has three components, these are

i. Compressor ii. Mist generator iii Nozzle

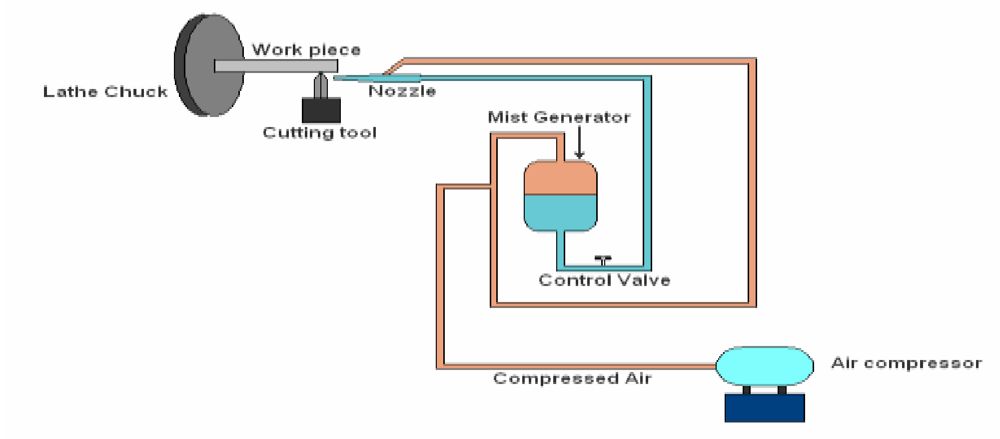

Fig 3. Shows the schematic representation of the experimental setup

The compressor used in this system acts as air supply unit and the main purpose is to supply air at a pressure, which is used in different components of the mist application system. Mist application system consists of two components (i) fluid chamber and (ii) nozzle.

The fluid chamber has an inlet port and an outlet port at the top and the bottom respectively. It is used only to contain the cutting fluid. It is connected to the compressor by a flexible pipe through the inlet port to keep the fluid inside the chamber under the constant pressure. It is required to maintain the flow into the nozzle over a long period of time during machining operation. The fluid chamber has been designed with larger capacity so as to able to supply fluid continuously during machining. In the inlet section of nozzle there are two inlet ports through which air and fluid can enter. High pressure air from the compressor enters into the nozzle mixes with the fluid which come from the fluid chamber with high pressure.

In mist application system a compressor is used to supply air at high pressure. The cutting fluid which is to be used is placed in the mist generator, and there is a connection of high pressure air line from the compressor with the help of flexible pipe at the bottom of the mist generator. When the air at high pressure enters the mist generator it carries a certain amount of cutting fluid along with it, and this cutting fluid coming out from the nozzle with the air coming in another from the compressor as a jet, which is applied to the hot zone. In the mist generator there is a regulating valve by which the flow rate of the cutting fluid can be controlled. The photographic and schematic views of the experimental setup are shown in Fig.3 respectively. During the experiment the thin but high velocity stream of mist is to be projected along the work tool interfaces as parallel as possible.

Selection of suitable cutting fluids

1. Type of machining processes
2. Type of machined workpiece material
3. Type of cutting tool material

1. Type of machining processes

The most important parameter in the selection of cutting fluids is the characteristics of machining process. Variety of machining processes would indicate relation between workpiece material-cutting tool-chip combinations. The most difficult machining process will need to use more cutting fluid. Machining processes were put in order according to the amount of usable cutting fluids quantity from the smallest amount to the highest amount [5]:

1. Grinding
2. Cutting with saw
3. Turning
4. Planning and shaping
5. Milling
6. Drilling
7. Reaming
8. Threading (using high cutting speed and low feed rate)
9. Threading operation with shape tools
10. Boring
11. Drilling deep holes
12. Gear production
13. Screwing with thread
14. Screwing with tap
15. Outer broaching
16. Inner broaching

The study concluded that this arrangement from using less cutting fluids to high would be a general approach and this would not provide detailed view of the type machining processes; the machined workpiece material and the cutting tool material and cutting tool geometry parameters could change this arrangement [5].

The heavy machining processes (for example broaching or screwing with tap) generally require middle or heavy cutting oils. Heavy cutting oils or the oils whose chemical components heavier active oils must be used in the horizontal broaching of steel. More oils have showed better performance in broaching operations compared to water based cutting fluids and their chemical components helped to make machining operation easier [5].

Emulsions and solutions can be used in vertical surface broaching operation; however the application of oil type cutting fluid would be more suitable. In threading operation, the interface between cutting tool and workpiece is small, but the interface is continuous. For this operation cooling characteristic of cutting fluid is required [5].

Drilling process may be more problematic. Cutting speed in drilling operation is generally low due to two cutting edges of drill tool. Moreover, the geometry of formed chip is different. Therefore the cooling effect of cutting fluid is more important in drilling process. In conventional drilling operation, emulsion oils and sulphur or chlorine additive mineral oils should be selected. These fluids can reduce friction and as a result less heat generation will be noticed. Using advanced drill tools such as drill containing holes for cutting fluid application can be preferred [5, 15].

2. Workpiece Materials.

The other factor for selection of suitable cutting fluids in machining processes is the type of workpiece material. The application of cutting fluids should provide easy machining operation in all materials. The cutting fluid is encountered widespread in engineering applications will be determined at below [5, 10, 14, 17].

Cast iron cast group of materials are brittle during machining they break into small size chips. The friction between cutting tool and chip is less due to small size chip formation. It was proposed that using emulsion cutting fluids increases surface finish quality and prevents dust formation during machining. The concentration of emulsion cutting fluid should be kept around 12% – 15% to decrease oxidation [10, 17].

In steel machining operation, generally the high pressure containing and additive cutting fluids are used. In stainless steel machining, high pressure cutting oils should be selected. Work-hardening properties in some steels would cause some problems during machining operation. However using sulphur added oils for this kind of steels machining leave stain over machined surface [10, 17-20].

For machining of heat resistant and difficult-to-cut steel alloys, water based cutting fluids are preferred, because temperature becomes higher in cutting area. The mixture ration of water based cutting fluids changes between 1/20 – 1/40. In some machining operations, using sulphur added mineral cutting oils is possible [16].

During machining of aluminium and aluminium alloys, high temperatures do not occur Waterless cutting fluids prevent the formation of “built up edge”, however this type of cutting fluids must be non active (leaving no stain) [10, 16].Machining of copper and copper alloys poses similar problems. The application of emulsion cutting fluids or thin mineral oils should be selected for copper and copper based alloys machining. High pressure additive cutting oils are preferred for brass machining [10, 16].In the machining of nickel and nickel alloys, the machining operation should be carried out as dry or using cutting fluids. Higher cutting speeds and feed rates should be selected when cutting fluids are used in the machining of these materials. Generally sulphured mineral oil as cutting fluid is preferred. Water based cutting fluids are used in turning with high cutting speed, milling and drilling operations. The applications of synthetic cutting fluids are possible in drilling and broaching operations [10, 16].

In machining of the difficult-to-cut materials such as titanium alloys, high temperature becomes an influential factor for selection of cutting fluid. Therefore the application of cutting fluid would eliminate the effect of generated heat during machining process. The selected cutting fluid must have both cooling and lubricating characteristics. The cooling factor of cutting fluid is more important in machining of titanium alloys due to high heat generation during machining operation. This would also induce to use higher cutting speeds. It is observed that lubrication properties of selected cutting fluids are preferred when low cutting speeds are selected. Emulsion oil can be selected in the machining of titanium alloys when cutting speeds are used; chlorine additive cutting oils are preferred when high cutting speed are selected [17,21-23].

In the machining operations of composites that used commonly nowadays, using cutting fluids is recommended. In particular the using cutting fluid has positive influence on the surface roughness quality [24].

3. Cutting tool materials

The third influential parameter for selection of cutting fluid in machining processes is the cutting tool material. Various cutting tool materials are commercially available for all kind of machining processes.

High speed steel cutting tools can be used with all type of cutting fluids. However waterless cutting fluids are preferred when difficult-to-cut materials are machined.

In case of the tungsten carbide (WC) cutting tools application, more cooling characteristics from cutting fluids are required. This is because of high generated heat in the interface of cutting tool and workpiece material. The negative effect of generated heat during machining with WC cutting tools causes rapid tool wear. Hence toll life will be shorter and surface finish quality falls [10, 14].

Cubic boron nitrate (CBN) and polycrystalline diamonds (PCD) cutting tools have been found important place in machining processes. However, these cutting tools are expensive and they can protect their characteristics in high temperature machining conditions. They are generally used in finish machining operation to obtain high dimensional accuracy and excellent surface finish quality. The application of cutting fluids is not necessary when machining operations are carried out with these cutting tool materials [10, 14].

Ceramic and diamond cutting tools can also protect their characteristics at high temperatures. They are generally used in finish machining operation. In using ceramic cutting tools, air is sprayed into the cutting zone. The water based cutting fluids must be used when diamond type cutting tool materials are used [10, 14].

CONCLUSION

The selection of cutting fluids for machining processes generally provides various benefits such as longer tool life, higher surface finish quality and better dimensional accuracy. These results also offer higher cutting speeds, feed rates and depths of cut. The productivity of machining process will be much higher with combination of selecting higher machining parameters. The material removal rates will be increased.

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. Nevertheless, the machining operations still require the use of cutting fluids in machining of some materials. Therefore, selection of the most suitable cutting fluid in any machining process must be carried out to obtain a maximum benefit. The selection of suitable cutting fluid is affected by mainly three factors in machining operations. These are the types of machining process, workpiece materials and cutting tool materials. The combination of these three influential factors would provide basic information for selecting the suitable cutting fluid.

The regeneration methods of used cutting fluids would also provide various advantages such as reducing cutting the fluids cost, disposals cost of used cutting fluids and nearly eliminating environmental pollution.

REFERENCES

1. M.B. Da Silva, J. Wallbank, "Lubrication And Application Method In Machining, Lubrication and Tribology" 50 (1998) 149-152.
2. E. Brinksmeier, A. Walter, R. Janssen, P. Diersen, "Aspects Of Cooling Lubrication Reduction in Machining Advanced Materials",Proceedings of the Institution of Mechanical Engineers, Journal of Engineering Manufacture, 1999, 769-778.
3. M. Sokovic, K. Mijanovic, "Ecological Aspects Of The Cutting Fluids And Its Influence On Quantifiable Parameters of the Cutting Processes", Journal of Materials Processing Technology 109 (2001) 181-189.
4. W.J. Bartz, "Ecological and Environmental Aspects of Cutting Fluids", Lubrication Engineering 57 (2001) 13-16.
5. M.A. El Baradie, "Cutting Fluids, Part I: Characterisation" Journal of Materials Processing Technology 56 (1996) 786-797.
6. M.A. El Baradie, "Cutting Fluids, Part II: Recycling and Clean Machining", Journal of Materials Processing Technology 56 (1996) 798-806.
7. P.S. Sreejith, B.K.A. Ngoi, "Dry Machining; Machining of the Future", Journal of Materials Processing Technology 101 (2000) 287-291.
8. H. Popke, Th. Emmer, J. Steffenhagen, "Environmentally Clean Metal Cutting Process-Machining on the Way to Dry Machining", Proceedings of the Institution of Mechanical Engineers, (1999) 329-332.
9. T.F. Glenn, F. van Antwerpen, "Opportunities and Market Trends in Metalworking Fluids", Lubrication Engineering 54 (1998) 31-37.
10. E.P. DeGarmo, J.T. Black, R.A. Kosher, "Materials and Processes in Manufacturing", Maxwell MacMillan Publication, (7^{th} Edition) New York, USA (1984) 578-581.
11. M.C. Shaw, "Metal Cutting Principles", Clarendon Press, Oxford, England, (1991), 292-332
12. J.A. Schey, "Introduction To Manufacturing Processes", McGrawHill International, ABD, 1987, 459-460
13. Kavuncu, "Cutting Oils in Metal Machining", Turkish Chambers of Mechanical

Engineers Publication, Istanbul (in Turkish).

14. W. Belluco, L. De Chiffre, “Testing Of Vegetable-Based Cutting Fluids By Hole Making Operations”, Lubrication Engineering 57 (2001) 12-16.
15. S. Ebbrell, N.H. Woolley, Y.D. Trimidas, D.R. Allanson, W.B. Rowe, “The Effects of Cutting Fluid Application Methods on the Grinding Process”, International Journal of Machine Tools and Manufacture 40 (2000) 209-223. ASM Committee, Machining of titanium alloys, Metals Handbook 19, ASM Publication, 499-507.
16. W. Belluco, L. De Chiffre, “Surface Integrity And Part Accuracy In Reaming And Tapping Stainless Steel With New Vegetable Based Cutting Foils”, Tribology International 35 (2002) 865-870.
17. R.F. Avila, A.M. Abrao, “The Effect Of Cutting Fluids On The Machining Of Hardened AISI 4340 Steel”, Journal of Materials Processing Technology 119 (2001) 21-26.
18. J.M. Vieira, A.R. Machado, E.O. Ezugwu, “Performance of Cutting Fluids During Face Milling of Steels”, Journal of Materials Processing Technology 116 (2001) 244-251.
19. O. Çak r, M. K yak, E. Altan, “Machining of Titanium and its Alloys”, Proceedings of the 2nd Machine Design and Production Technologies Cenference, 26-27 September 2003 Konya, Turkey 21-30 (in Turkish).
20. E.O. Ezugwu, Z.M. Wang, “Titanium Alloys And Their Machinability - A Review”, Journal of Materials Processing Technology 68 (1997) 262-274.
21. E.O. Ezugwu, J. Bonney, Y. Yamane, “An Overview of the Machinability of Aerospace Alloys”, Journal of Materials Processing Technology 134 (2003) 233-253.
22. N.P. Hung, S.H. Yeo, B.E. Oon, “Effect Of Cutting Fluid On The Machinability Of Metal Matrix Composites”, Journal of Materials Processing Technology 67 (1997) 157-161
23. Aronson, R.B. “Machine Tool 101: Part 6, Machine Servers,” Manufacturing Engineering (June, 1994), 47-52.
24. Sluhan, C.A. “Selecting the Right Cutting and Grinding Fluids,” Tooling & Production (May 1994), 40-50.
25. Tuholski, R.J. “Don’t Forget the Cutting Fluid,” Journal of Industrial Technology (Fall 1993), 2-5.
26. Silliman, J.D. and R. Perich. “Cutting and Grinding Fluids: Selection and Application - Second Edition,” (Dearborn, Michigan: Society of Manufacturing Engineers, 1992), p.216.
27. Villena-Denton, V. “Cutting Fluids Book Hot Off the Press,” Lubricants World (May 1994), 25.
28. Bienkowski, K. “Coolants & Lubricants - Staying Pure,” Manufacturing Engineering (April, 1993), 55-61.
29. Doyle, D. and B. O’Keeffe. “Decoding Hazardous Waste Regulations,” Manufacturing Engineering (March, 1993), 53-54.

30. Bienkowski, K. "Coolants & Lubricants - The Truth," Manufacturing Engineering (March, 1993), 90-96.
31. Lukas, J. "Auto Industry Seeks Universal Fluids," Lubricants World (May, 1994), 30.
32. State of Ohio Environmental Protection Agency. "Extending the Life of Metal Working Fluids," (Columbus, Ohio: Pollution Prevention Fact Sheet No. 11, March 1993), p. 4.
33. Foltz, G. "Definitions of Metalworking Fluids."
34. Koelsch, J.R. "Honing Fluid Performance," Manufacturing Engineering (February, 1994), 51-55.
35. Iowa Waste Reduction Center. "Cutting Fluid Management in Small Machine Shop Operations - First Addition," (Cedar Falls, Iowa: University of Northern Iowa, 1990), p.43.
36. Oberg, E., F.D. Jones, H.L. Horton and H.H. Ryffel. "Machinery's Handbook," (New York: Industrial Press Inc., 1992), p. 2543.
37. Jarrard, A. "Metalworking Fluids Management Programs," Modern Machine Shop (June, 1993), 81-84.
38. Hydrick, H. "Coolant Management Concern Invites Change," Lubricants World (May, 1994), 29 and 34.
39. Lukas, J. "Fluids Getting More Attention from Management," Lubricants World (July, 1994), 26.
40. Lukas, J. "What's in the Fluid Often More Important Than the Fluid Itself," Lubricants World (May, 1994), 26.
41. Hoobler, G.L. "Coolant Management: A User's Introduction and Guide to Waste Minimization."
42. Carmody, D.P., A.B. Law, and G.L. Willingham. "Microbial Control and its Impact on Waste minimization sssof Metalworking fluids."
43. Lukas, J. "Chicago Section Examines Myriad Topics," Lubricants World (May, 1994), 28.
44. Saunders, J. "Self-Emulsifiable Base Oil Enhances Fluids," Lubricants World (May, 1994), 31-32.
45. Sluhan, W.A. "Disc-Bowl Centrifuging of Water-Miscible Fluids," Cutting Tool Engineering (December 1988).
46. Sluhan, C.A. "Considerations in the Selection of Coolants Used in Flexible Machining Cells," Society of Manufacturing Engineers Technical Paper MS86-124, (Dearborn, Michigan: SME, 1986), 1-5.
47. Sluhan, W.A. "Coolant Management: Rx for Ending Coolant Headaches," The Carbide & Tool Journal (March/April 1985).
48. Winkler, J (1998) Dry Drilling [On-Line] www.ifw.uni-hanover.de/industrie/ind_main_e.htm

49. Dry Machining of Plutonium Parts, Case Study, Los Alamos National Laboratory, U.S. Dept. of Energy,

50. Vaughn, Michael J. (1999) Dry Machining: Tech 590w Investigative Report, Purdue University

51. Heine, H. J. (1996) Environmentally Conscious Manufacturing: Dry Machining, A Promising Option (NTIS No. PB96-129093 KZO)

52. Makiyama, Tadashi, (2000) Advanced Near Dry Machining System, R&D Division, HORKOS CORP. 4th Annual NCMS Fall Workshop Series

53. Rozzi, J. "Final Report: Low Cost Machining Without Cutting Fluids,"National Center for Environmental Research.

54. S. Paul, "Beneficial Effects of cryogenic cooling over dry and wet machining on tool wear and surface finish in turning ANSI 1060 Steel", Journal of Materials Processing Technology

55. "Metalworking Fluids: Safety and Health Best Practices Manual,"U.S.Dept. of Labor, OSHA, 2001, www.OSHA.gov.

56. DeMarco, Nancy. "Muddy Waters," Lubes–n-Greases, Vol. 8, Dec 2002, P. 22.