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Selection of cutting fluids in machining processes

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ABSTRACT

Purpose: During machining operation, friction between workpiece-cutting tool and cutting tool-chip interfaces result high temperature on cutting tool. The effect of this generated heat 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.

Design/methodology/approach: 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.

Findings: As a result, important benefits would be achieved such longer tool life, easy chip flow and higher machining quality in the machining processes. The selection of cutting fluids should be carefully carried out to obtain optimum result in machining processes. Various factors are affecting the selection of cutting fluid type in machining operation such as type of workpiece materials, cutting tool material and the method of machining processes.

Research limitations/implications: In this study, the selection of cutting fluids for machining processes was examined. The effects of workpiece material, cutting tool and machining process type were determined in detail.

Originality/value: In this study, the studies about cutting fluid application in machining processes have been evaluated. The selection criteria of cutting fluids have been examined. Suitable cutting fluids for various material machining processes have been determined according to cutting tool materials.

Keywords: Machining; Tool materials; Cutting fluids; Engineering materials

1. Introduction

The machining processes have an important place in the traditional production industry. 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.

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.

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]. New approaches for elimination of cutting fluids application in machining processes have been examined and "dry machining" was presented as a important solution [7, 8]. The development of new cutting tool materials also helped dry machining method to be a positive solution for cutting fluids applications. However, the usage of cutting fluids has been increased due to high production levels in the world. According to 1998 values, approximately 2.3x109 liter cutting fluids have been used in the machining operations and its cost value was around $ 2.75x109. North America had a big ratio, Europe continent was in the thirth order after Asia continent [9].

The first study about cutting fluids had been determined by W.H. Northcott in 1868 with a book entitled "A treaties on lathes and turning". In the middle of 1890's, F.W. Taylor emphasized that using cutting fluids would allow to use higher cutting speeds resulting in longer tool lifes and higher material removal rates [10]. It had been concluded that the application of cutting fluids in machining processes would make shaping process easier [11 -14].

In this study, the studies about cutting fluid application in machining processes have been evaluated. The selection criteria of cutting fluids have been examined. Suitable cutting fluids for various material machining processes have been determined according to cutting tool materials.

2. Selection of cutting fluids

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

a. Cooling effect
b. Lubrication effect
c. Taking away formed chip from the cutting zone

The cooling effect of cutting fluids is the most important parameter. It is necessary to decreasie 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].

3. Selection of suitable cutting fluids

The selection of cutting fluids in machining processes depends on various factors. The selection of cutting fluids is carried out according to factors mentioned below [5, 10, 14]:

a. Type of machining processes
b. Type of machined workpiece material
c. Type of cutting tool material

3.1. 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. The excellent literature survey in cutting fluids application provided same important data; 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]

For the super finishing processes like honing, specially prepared oils should be used as cutting fluid due to different machining characteristics.

In turning, milling and grinding machining processes water based cutting fluids are more suitable due to using new cutting tool materials such as hard metals and high cutting speeds. The contact period between cutting tool and workpiece material is small when high cutting speeds are used. Therefore penetration of cutting fluid will not be sufficient. The type of crater wear on cutting tool can be seen more oftrn. Water based cutting fluids will reduce the effect of generated heat on cutting tool wear [5, 16].

Some emulsion oils and chemical cutting fluids prepared especially for grinding procedure; the concentration of prepared cutting fluids are between 1:25 and 1:60 and in the form of mixture with water. Material removal rate in grinding will be higher when higher density concentration (2,5% – 10%) cutting fluids are used. This would also provide a better surface finish quality. Moreover, the required grinding power would decrease [5,16].

Geometric form of grinding wheels has an important role in grinding operations such as thread grinding. Cutting oil or EP additive emulsion oils should be selected for this kind of grinding processes. Oil based cutting fluids have decreased surface spoils in grinding. Grinding oils decrease friction and therefore heat becomes less effective. This condition provides a higher grinding removal rates due to using a higher grinding depth. Moreover, lower surface roughness values would be obtained and grinding wheel break would occur more rarely. The effect of heat on the machined surface causes problems like unremoved chips on ground surface, burning and smelling, etc. [5].

3.2. 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].

3.3. 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].

4. Conclusions

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.

However, environmental legislations have been forcing to eliminate or reduce cutting fluid application in machining processes since beginning of 1970's. Moreover the application of cutting fluids has negative effects on health of workers. 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.

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