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APPLICATIONS OF CUTTING FLUIDS ON MACHINING

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Abstract: *In the last decades a lot has been discussed about the suitability of using cutting fluid to cooling and lubricate machining processes. The use of cutting fluid generally causes economy of tools and it becomes easier to keep tight tolerances and to maintain workpiece surface properties without damages. There are various advantages of cutting fluid application as increasing tool life, decreasing machining times and improving surface quality. However, there are some disadvantages of cutting fluid as high costs relating storages, preparation, filtration and recycling, pollution harmful to environment. In the other hand, it brings also some problems, like fluid residuals and human diseases. Because of environmental and health problem some alternatives has been sought to minimize of cutting fluid in machining operations. Various methods such as spray application, MQL, dry machining and internally cooled have been offered in machining processes. However, there are also situations where cutting fluid must be used, such as gear making, broaching and honing. Therefore, topics like kinds and methods of applications of modern cutting fluids and what are new in this area will unavoidably are considered.*

The results of investigations on the development and use of methods of applying cutting fluids were given in this paper.

Keywords: *Cutting Fluid, Machining, Environmental and Health.*

1. Introduction

Machining is a material removal process, in which a sharp cutting tool is generally used to mechanically cut material to produce a desired geometrical part. Machining is applied to achieve the desired geometry, tolerances and surface quality on the workpieces. Machining provides important advantages in a short time and economically such geometric dimensioning, tolerance and surface quality. Machining is the most commonly used process in manufacturing. It is able to produce a very good surface finish with high precision and accuracy.

Heat is generated during machining operations as known. Thermal damage and wear on the cutting tool continuously increases and this leads to shorter tool life. Moreover, the wear on cutting tool causes to poor surface quality on workpiece. The rate of tool wear strongly depends on the cutting temperature, therefore, any measures which could be applied to reduce the cutting temperature would reduce the tool wear as well. Figure 1 shows the parameters that influence the rate of tool wear [1].

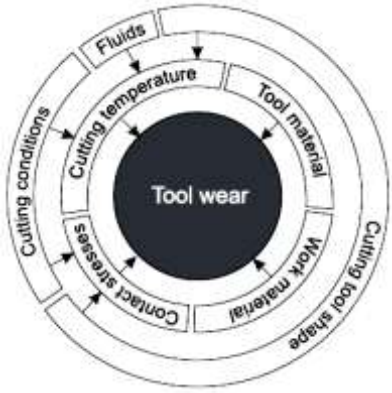


Fig. 1. Cutting tool wear as a function of basic process parameters [1]

The energy dissipated in cutting operations is largely converted into heat, raising the temperature of chip, tool, and workpiece. The cutting fluid, if used, is an excellent heat sink. There are three sources (Fig. 2) for heat development:

1.the shear process itself.

2.the tool-chip interface friction.

3.the flank of the tool rubbing the workpiece

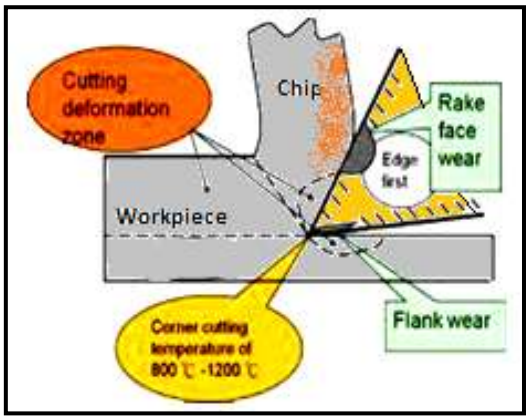


Figure 2. Typical wear pattern in cutting tool

Most of the heat produced is carried by the chip implying that the shear process (plastic deformation) is most effective in producing heat. Cutting fluids are used to remove negative effects of heat. Figure 3 shows that tool wear is affected by cutting temperature depending on the time.

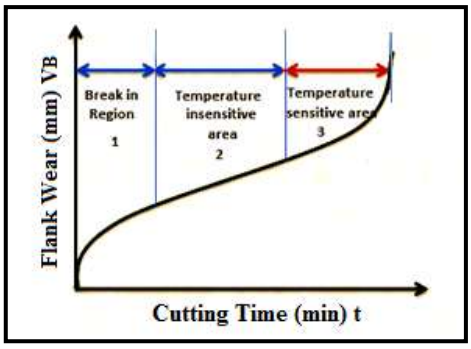


Figure 3. Tool wear variation with respect to time.

Cutting fluids are employed to minimize influence of heat on cutting tool. There are various advantages of cutting fluids as increasing tool life and improving workpiece surface quality. Besides of these there are some disadvantages as follows, pollution harmful to environment and health problems. Nowadays, many approaches are presented to solve the problems of cutting fluid in cutting process. Various methods such as MQL or internally cooled cutting tools have been offered as an alternative methods in machining operations.

2. Cutting Fluids

Cutting fluids have been using in machining operations to lubricate the chip-tool and tool-workpiece interfaces, remove heat from the workpiece and cutting zone, flush away chips from the cutting area, and inhibit corrosion [2].

The global lubricant demand was 39.4 million tons in 2015 and it is expected to reach 43.9 million tons in 2022. The industrial lubricant market can be segmented into several categories taking into account their applications. Some of the most used lubricants are gear oils, hydraulic lubricants and engine oils. Cutting fluids represent about 5% of the global lubricant market, with Asia as the largest consumer. Approximately, 85% of the cutting fluids used are mineral based. However, the estimated values deviate significantly because of the processes diversity [3]

Cutting fluids are widely used in machining processes. The advantages and disadvantages of cutting fluids are given in Table 1. The main cutting fluid roles are cooling, reducing friction, removing metal particles, and protecting the workpiece, the tool and the machine tool from corrosion. However, the use of cutting fluids has also associated some disadvantages such as their cost, environmental impact and health hazards to workers. In machining processes, sustainable manufacturing can be addressed for example, by reducing the consume of electric energy, improving the tool life and the surface quality of the workpiece. The main alternatives include dry machining, minimum quantity lubrication (MQL), cryogenic cooling, gaseous cooling and nano-fluids [3].

Table 1. Cutting fluids advantages and disadvantages in machining operations[3].

Advantages	Disadvantages
Increase tool life	Cost related to cutting fluid purchase, storage, maintenance, waste fluid disposal
Lower cutting forces and power required	As time passes it can cause workpiece and machine tool damages due to a bad maintenance
Higher cutting speeds and feeds rates	Environmental impact
Reduce post-process heat treatments	Worker health hazards
Better workpiece quality	

Cutting fluids reduce the heat, wash away the chips, and protect the machined surface from oxidation. It is a coolant as well as a lubricant. The mechanism of cutting fluid action involves capillary action in which case the fluid should have small molecules and proper wetting of the surface. The cutting fluids are applied in flood or in mist conditions. Flood cooling is applied on gear making, broaching, honing and drilling in generally. Mist cooling is applied in grinding and turning. Selection of the cutting fluid depends on the workpiece, on the machine tool and on the operator safety [4].

However conventional cutting fluids growing public health concern worldwide and following this issues, in 2008, Aggarwal et al. [5] have written the following limitations towards conventional cutting fluids:

- Environmental pollution due to chemical dissolition of cutting fluid.
- Biological problems as skin problems and respiratory problems when come in physical contact with the cutting fluid.
- Contamination of water and soil pollution during disposal.
- The need for additional floor space and additional system for pumping, storage, refining, recycling, cooling, etc.
- Increase of the cost of disposal of cutting fluids.

3. Types Of Cutting Fluid

The modern lubricants are most often the products of the petroleum chemistry. By the physical state, lubricants (Fig. 4) can be divided into liquids, solids, gaseous and also plastics. Among these, liquid lubricants are the most widely used. Liquid lubricants can be classified based on their origins [6, 8].

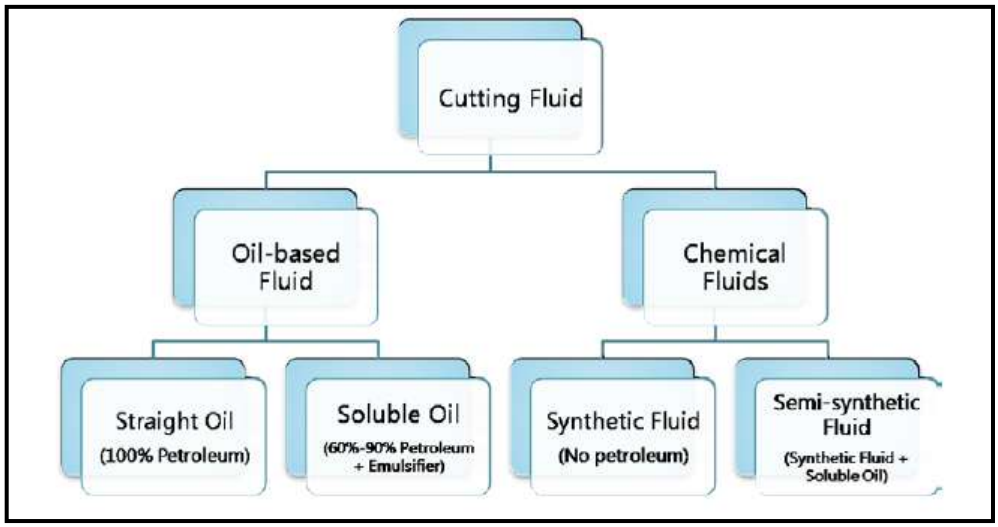


Figure 4. Classification of cutting fluids [7]

1. Straight oils

Straight oil is made up from entirely mineral oil or vegetable oils and is used primarily for operations where lubrication is required. Although being excellent lubricating oil, their heat transfer capabilities exhibit very low. Mineral oil, which is highly flammable, has low efficiency at high cutting speed and relatively high cost.

2. Soluble oils

Soluble oil is a mixture of oil and water and has increased cooling capacity than straight oil and provided rust protection. This type water-based cutting fluids is suitable for turning, milling and grinding process. In addition, water-based cutting fluids reduce the effect of heat generated by tool wear.

3. Semi-synthetics

It contains inorganic material or other water-soluble compounds. Adding emulsified oil in synthetic cutting fluid results in semi-synthetic fluids that have properties combined. It is also better than soluble oil, but tarnishes easily when exposed to other machine fluids and can cause dermatitis risk to workers.

4. Synthetics

Synthetic oils are a chemical liquid containing inorganic or other chemical that are soluble in large quantity of water and offer superior cooling performance. Synthetic lubricants were not initially favored due to their high cost of production. However, as time passes synthetic oils have gained more attention and applications. Synthetic oils can be used for more specific and high performances applications such as operating at extreme temperatures. Synthetic oils include synthetic hydrocarbons such as polyalkylene glycol, various esters and polyalphaolefins. The cutting fluids properties are given in Table 2. Regarding towards to green manufacturing, biodegradable lubricant plays important role.

Table 2. *Cutting fluids properties [3, 7]*

	Straight oils	**Emulsions**	**Semi-synthetic**	**Synthetic**
Aspect	Oily	Milky	Translucent	Transparent
Lubricity	Excelent	Good	Good	Poor
Cooling	Poor	Good	Good	Good/ Excellent
Chip removal	Moderate	Moderate	Moderate	Moderate
Corrosion control	Excellent	Poor	Good	Good
Microbial control	Excellent	Poor	Good	Excellent
Fire	Hazard	Non-flammable	Non-flammable	Non-flammable
Other disadvantages	Limited to low-speed operation create mist	Evaporation losses foam tendencies	Hard water influence foam tendencies	Easily contaminated by other processing fluids

4. Cooling Techniques

The application types of cutting fluids are given in Figure 5.

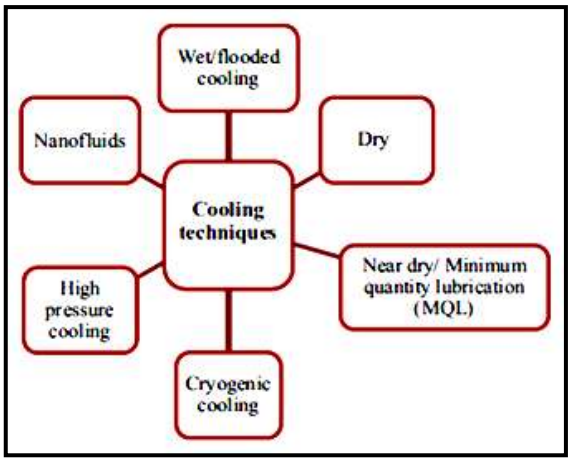


Figure 5. Cooling techniques

1. Flooded (wet) cooling

Flood (wet) cooling is a technique in which cooling jet aimed at the active zone for cooling, lubricating and get rid of chips produced during machining. This method is suitable for the cutting processes in which excess heat energy is produced.

2. Dry machining

Dry cutting is a process without the use of any cutting fluid during machining.

3. Minimum quantity lubricant (MQL)

Small quantities of cutting fluid is injected with an air pressure in the form of fine droplets at high velocity into the cutting zone.

4. Cryogenic cooling

Cryogenics cooling is the use of gases in minus temperatures. Liquid nitrogen and carbon dioxide are widely used in cryogenic cooling.

5. High pressure cooling (HPC)

Coolant jets are used with very high pressures which around 100–1000 bar in this system. The coolant jet is directed at very high pressure exactly on the rake face of the cutting tool.

6. Nano-fluid

Nano-fluids are defined as colloidal suspensions of nano-particles in a base fluid and these suspended metallic or

nonmetallic nano-particles change the transport properties and heat transfer characteristics of the base fluid

Figure 6 illustrates the relative percentage of oil, water, and additives found in water-soluble metalworking fluids.

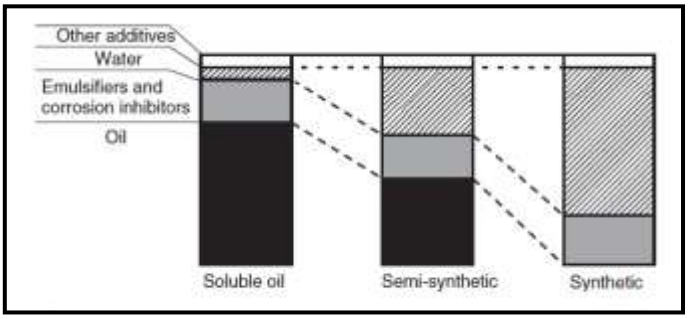


Figure 6. Relative proportion of water, oil and additives in water-soluble metalworking fluids[9].

Table 3. Presents a qualitative estimation of the environmental impact of various lubricant/cooling systems used in the machining taking into account [3].

Table 3. *Qualitative estimation of cooling environmental impact [3].*

	Residue	**Dangerous subtances**	**Mist and emissions**	**Workers healt hazards**
Cutting fluid	*****	****	*****	*****
Dry machining	*	*	*	*
MQL	**	**	***	***
Cryogenic cooling	*	*	**	*
Gaseus cooling	*	*	*	*
Nanofluids	****	Unknown	****	Unknown

(*) Very low, (**) Low, (***) Medium, (****) High, (*****) Very high

The purposes of cutting fluid in machining operations are to cool the workpiece and tool, reduce friction and through away the chips. The cutting fluid contributes significantly toward machining cost and also possesses environmental threats. There are some attempts to minimize the amount of cutting fluid in machining. The cost effect of different cutting fluids is given in Table 4.

The tangible cost factors to be considered include: initial cost per liter, mix cost, production rates, tool life, overheads, part cleaning costs, machining cost per piece, cutting fluid life, scrap caused by rusting, rework costs due to rust, cost of fluid disposal. The intangible cost factors include: cleanliness of machines and the workshop, operator satisfaction and hygiene, smoke problems, work accuracy, ease of handling and viewing parts, adaptability to different jobs, safety, fire hazard, and disposability.

Table 4. Qualitative estimation of cooling system costs. [3]

	Fluid consumption	**Equipment cost**	**Cleaning cost**	**Disposal cost**
Cutting fluid	*****	****	*****	*****
Dry machining	*	*	*	*
MQL	**	***	**	**
Cryogenic cooling	***	*****	*	*
Gaseus cooling	***	****	****	***
Nanofluids	****	****	****	*****

(*) Very low, (**) Low, (***) Medium, (****) High, (*****) Very high

Dry cutting is easy and cost-effective. However, cryogenic and nanofluid applications are difficult and expensive. The effect of sustainability of the cutting fluids versus cost is given in fig 7. Sometimes the cutting fluid costs are more than twice (fig 8) the tool-related costs[10, 11].

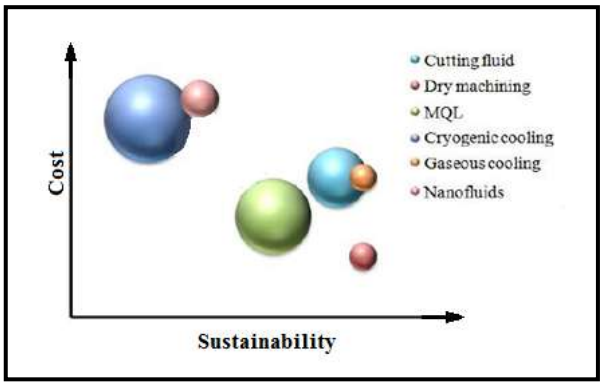


Figure 7. Cost of cooling system in machining as a function of sustainability [3]

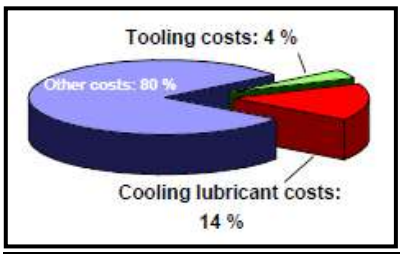


Figure 8. Cost of cutting fluid versus other cost. ***[10]***

5. Results And Conclusions

Cutting fluids play an important role on machining operations. However, they use have some drawbacks such as their negative effects over the environment and workers health as by costs associated such as the equipment, fluids purchase and waste fluid treatment. Conventionally, mineral oils were used as cutting fluids. However, the mineral oils cooling capacity is limited and therefore soluble oils were seen as a good alternative. Nevertheless, soluble oils contain water which is susceptible to bacterial attack. Synthetic lubricants are superior in many regards, but cost is higher. The alternative techniques such as MQL, cryogenic, gaseous cooling and nano-fluids have been implementing in some machining processes, even may become more efficient than conventional cooling. The best environmental alternative is dry machining since completely removes the cutting fluid and ensures a clean atmosphere and workers safety, though it has many application limitations. However, there are still applications where cutting fluids cannot be removed such as gear making, broaching.

6. References

1. http://me.emu.edu.tr/me364/ME364_cutting_wear.pdf
2. Adler D. P., Hii W.W.S, "Examining the Role of Cutting Fluids in Machining and Efforts to Address Associated Environmental/Health Concerns", Department of Mechanical Engineering, Engineering Mechanics Sustainable Futures Institute, Michigan Technological University
3. Benedicto E., Carou D., Rubio E.M., "Technical, Economic and Environmental Review of the Lubrication/Cooling Systems used in Machining Processes", Proc.Eng., V.184, (2017), pp. 99-116
4. http://www.public.iastate.edu/~mebbs/courses/ME322/Machining.html
5. Aggarwal A., Singh H., Kumar P., Singh M., "Optimization of Multiple Quality Characteristics for CNC Turning under Cryogenic Cutting Environment Using Desirability Function", Journal of Materials Processing Technology, V. 205, (2008), pp. 42–50
6. Osama M., Singh A., Walvekar R., Khalid M., Gupta T.C.S.M., Yin W.W, "Recent developments and performance review of metal working fluids", Tribology International 114 (2017) 389–401
7. Wank Z., "The Correlation Between the Penetration Force of Cutting Fluid and Machining Stability", A Thesis of the Degree of Master of Science, Worcester Polytechnic Institute, May 2010
8. Liew P.J., Shaaroni A., Sidik N.A.C., Yan J., "An overview of current status of cutting fluids and cooling techniques of turning hard steel", International Journal of Heat and Mass Transfer 114 (2017) 380–394
9. Steven J. Skerlos, "Environmentally Conscious Manufacturing at the Machine Tool", The University of Michigan, V1, December 15, 2006
10. http://www.zet-chemie.de/wp-content/uploads/2016/04/1_Info_Kuehlschmierstoffe_in_der_ Metallbearbeitung_englisch.pdf
11. Astakhov V.P., "Ecological Machining: Near-Dry Machining. In: Davim JP (ed) Machining: Fundamentals and Recent Advances" 2008, Springer, London