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Alternatives for Coolant Oil - A Review

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***Abstract*: Machining is one of the largest and most widely used methods of producing segments in industries. For this purpose, cutting fluids play an important role in minimizing production time, cost and energy in different machining operations. In this research at first, influence of parameters in machining such as surface roughness, machining temperature and environmental effects were investigated. Furthermore, the disadvantages of using cutting fluids especially, the effects of cutting fluids on human health due to the growth of bacteria in the coolant oil and the ecological problems in the industry like disposing of the of the coolant oil are discussed. Hence to overcome such problems an attempt is made regarding of green machining including the vegetable type cutting fluid like Neem oil and Water melon seed oil. Finally, the possibility of the future trend of machining process that includes the nano fluids made up of the nano particles is introduced. The effect on the nano fluids on machining parameters such as surface roughness and temperature effects and the comparison between the conventional types machining with the nano lubricants is discussed. Finally the difficulties of applying this nano fluid in machining are also reviewed.**

***Keywords*: Coolant oil, growth of bacteria, ecological problems, alternatives, vegetable-based coolant, machining parameters, nanofluids, nanoparticle**

1. Introduction

Industrial development and application of new methods for improving production processes require studies in various fields, especially in the machining [1]. Manufacturers always look for higher productivity and profits. To increase the productivity the cutting fluids play an important role. In metalworking operations, the frictional resistance can be reduced by adding coolant oil which acts as a lubricant between the surfaces [2]. Two types of cutting fluids are generally used, depending upon the requirements of the work. They are the straight and the soluble oils. Straight oils are petroleum or fatty oils, or mixtures of the two, with or without chemical treatment or additives to enhance lubricity [3]. Soluble oils are usually petroleum oils mixed with emulsifying agents such as soaps of petroleum sulfonate, rosin, tall oil or fatty oil. The straight oils are used without mixing or are mixed with other oils, while the soluble oils are usually mixed with varying quantities of water to form stable, milky emulsions [4].

2. Growths of bacteria in soluble oil emulsions

Bacteria are not known to grow in straight oils, as water is necessary for synthesis of cellular materials. Growth in this medium is thought to be responsible for several undesirable occurrences such as obnoxious odors, discoloration of the emulsion, and an increase in acidity with resultant breaking of the emulsion [5]. Also, some workers are of the opinion that these bacteria are responsible for dermatitis (a type of skin disease caused due to bacterial contact with skin) of workers in contact with the oils. Bacteria grow readily in soluble oil emulsions used in industry. This work, however, is concerned with several hitherto unreported aspects of growth of bacteria in soluble oil emulsions as well as confirming some of the observations of Duffett et al., (1943) [6].

Table 1
Effect of oil concentration on the time of bacteria growing in soluble oil emulsions

Percentage of oil	Mean generation time in minutes
10	173
1	193
0.1	247
0.01	289
0.00	367

The Table 1, shows the relation between the percentage of oil in the coolant oil and the mean time generation of bacteria in minutes. It clearly shows that the greater the percentage of oil then greater the mean time for the growth of the bacteria.

Table 2
Increase of bacterial populations in two cutting fluids in a machine shop

Number of days	Bacterial growth in sample(app)
1	2,00,000
4	2,70,000
7	1,23,00,000
10	4,60,00,000
15	9,00,00,000

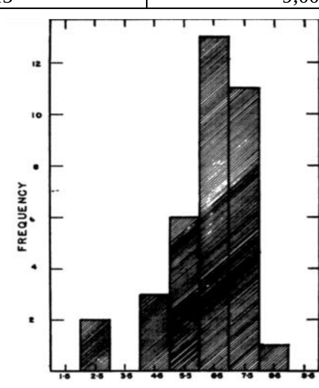

Fig. 1. Frequency distribution of bacterial populations in samples of soluble oil emulsions

The Table 2, shows the relation between the number of days of the coolant oil stored and the amount of bacteria growing approximately in the sample oil taken in the shop floor. It clearly shows that the number of days keeping the oil sample for longer days the number of bacteria growing in the sample grows more [7].

The Fig. 1, clearly shows the logarithmic growth of the frequency of bacteria in the test samples taken from various industries under different conditions. The unmaintained environment of the sample shows that the growth is more in the test samples.

3. Ecological problems of conventional cutting fluids

Due to the toxic effect of cutting fluids caused due to the growth of the bacteria, the environmental factors associated with machining become an emerging problematic aspect in recent years. It is reported around 40 % of all occupational infections of the operators were due to skin contact with cutting fluids due to the bacterial infection [8]. The International Agency for Research on Cancer (IARC) reported that petroleum-based cutting fluids which contain heterocyclic and polyaromatic rings is carcinogenic and exposure to it could result in occupational skin cancer (Abdalla et al. 2007) [9]. Owing to these hazardous substances, toxic and less biodegradability cutting fluids causes lots of techno-environmental problems and serious health problems like lung cancer, respiratory diseases, dermatological and genetic diseases (Ozcelik et al. 2011) [10].

Besides, the bacterial growth in the cutting fluids significantly leads to the presence of microbial masses and particularly endotoxin at the shop floor atmosphere. Thus, biocides additive are added in order to control the bacterial growth in the cutting fluids [11]. However, discharging the cutting fluids containing biocides could affect the natural decomposition process and some municipalities forbidden the disposal of biocides into the sewage systems. Many of the available biocides are also found to release formaldehyde, which is a possible carcinogen [12].

The widespread use of petroleum based cutting fluids cause significant environmental pollutions throughout their life cycle. Statistics show that the purchasing, preparation, maintenance and the disposal costs related to the cutting fluids are approximately 16 % of the total manufacturing costs [13]. Therefore, the focus on cutting fluids has shifted from biodegrability to renewability over the years in order to protect our precious environment. The current focus should address several aspects of an environmentally adapted cutting fluid in terms of biodegrability, toxicity, renewability, bio accountability and biomagnifications [14].

4. Newly developed vegetable-based cutting fluids

Numerous literatures show that vegetable-based cutting fluids have better performances and they are more readily biodegradable. Ozcelik et al. 2013 investigated the effects of various vegetable-based cutting fluids on specific energy, tool life, and surface roughness for end milling. The authors concluded that vegetable based cutting fluids achieved the objective of cleaner manufacturing and simultaneously improved the machining performance in term of specific energy, tool life, and surface roughness. Thus, vegetable-based cutting fluids have high potential to be considered as alternative cutting fluids to semi synthetic cutting fluids [15].

For example the Neem oil and Melon Seed oil can be used as coolant oil. Rather than coating the tool to machine high strength alloys, it found to be a simple alternative. Physiochemical properties such as viscosity, flash point, pour point, specific gravity were studied. Specific gravity of Neem seed oil was 0.9304 and Water Melon seed oil was 0.9324. The flash point for Neem seed oil was obtained as 160°C, Water melon seed oil 120°C [16].

Table 3
Results of physiochemical analysis of two vegetable oils

Properties	Neem oil	Water melon seed oil
Specific gravity	0.9302	0.9322
Pour point (˚C)	+8	-8
Flash point (˚C)	160	120
PH	6.12	6.56
Kinematic Viscosity (m^2/s)	7.08	7.52

The Table 3, shows the results of the physiochemical properties of the two vegetable cutting fluids namely neem oil and water melon seed oil. The above physiochemical properties like specific gravity, pour point, flash point, PH and kinematic viscosity are listed for those two vegetable based cutting oil.

Table 4
Temperature results of 50% oils and 50% water at 250 rpm

Sample	Depth of Cut mm	Machine reading ˚C
Conventional	3	45
Neem oil	3	38.1
Water Melon seed oil	3	39.32
Dry sample	3	51

The Table 4, clearly gives the comparison between the different types of machining with the same amount of the depth of cut of 3mm. It results from the various machine readings temperature with respect to the type of machining like conventional, neem oil, water melon seed oil and dry machining at 250rpm [17].

5. Future trend of machining

Although bio-based (vegetables) cutting fluids are not perfect in all aspects, it has the least negative effects to the environment compared to other cutting fluids. Undoubtedly, vegetable based cutting fluids have successfully led to economic benefits by way of reducing the cleaning cycle time and disposal cost. Based on the statistics, the demand for bio-based lubricants is expected to increase around 58 % or 0.29 Mt in 2018 compared to 2011. Therefore, future research should concentrate more on the solutions to overcome the drawbacks of the vegetable-based cutting fluids such as low thermal and oxidative stability to meet the demand [18].

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Nowadays, using nanotechnology in science and industry improves yield of the different processes. Hence, in machining operations nanotechnology is used to increase the productivity. With the low cost and outstanding properties, nano particles have shown enormous potential to be an innovative, effective alternative to flood lubrication due to environmental issues. Therefore, future research should concentrate on the optimum utilization of the high performance of nano-based lubricants productivity in the machining industry in order to improve machining performance and cost reduction by abandoning conventional cutting fluid [19].

6. Nano fluids

Nanofluids are produced by distribution of solid nano particles in a base fluid like water, oil, ethylene glycol and so on. In this method, increasing the thermal conductivity factor is the main idea for improving heat transfer ability. Thermal conductivity factor of solid particles are greater than fluids. Current study focuses on the utilizing of nanofluids as coolant and lubricant [20].

Nano particles in base fluid lead to rise in thermal conductivity, convective heat transfer coefficient and viscosity. Additionally, they have unique attributes which differentiate them from usual materials. This special features result in many benefits and advantages of applying nanoparticles in industry [21]. Wide researches have been carried out on thermal characteristics of nanofluids in recent years and approximately all of them have shown remarkable improvement. Current study focuses on the utilizing of nanofluids as coolant and lubricant and their influence on cutting parameters in machining processes. Finally, a brief review has been done on a number of published papers by different researchers [22].

A. Effect of nano fluid on machining parameters

In order to improve cooling and lubrication ability of a fluid, various investigations for using different nanoparticles in water base or other solvents have been conducted. The effects on machining process are reflected on the surface roughness of the work piece [23].

1) Surface roughness

Quality of machined surface when nanofluid is applied as coolant always is better than dry condition or other conventional fluids. The reason is more efficient lubricating, decrease in machining forces, depletion in friction and higher heat transfer coefficient due to more heat extraction from cutting zone that cause decrease in micro crack pressure and workpiece temperature so improvement in surface finished [24]. In the bar chart of Fig. 1 surface roughness of workpiece during turning operation with Al2O3 nanofluid (with different volume concentrations), MQL (minimum quantity lubrication) and dry has compared with each other. It seems that, if nanofluids apply properly surface roughness will decline. Similar results are seen in other researches with different nanofluids and machining conditions [25].

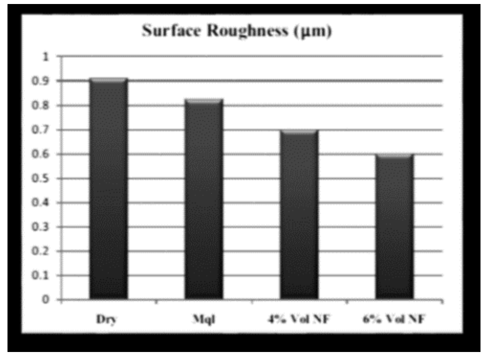

Fig. 2. Effect of nanofluids on the workpiece surface roughness

The Fig. 2, shows the comparison of different types of coolant in improving the surface roughness of the product. It is clearly known that among the dry machining, minimum quantity lubrication, 4% volume of nano fluid and 6% volume of nano fluid; the higher the volume of nano particles added higher the surface finish is obtained [26].

2) Machining temperature

Difference between using nanofluids as metal working fluid and other conditions in turning are shown in Fig. 3. Nanofluids have better heat transfer features (especially higher thermal conductivity) and show wide influence on workpiece and tool temperature. Moreover, nanofluids with reduction in friction between tool and workpiece lead to lower heat generation [27].

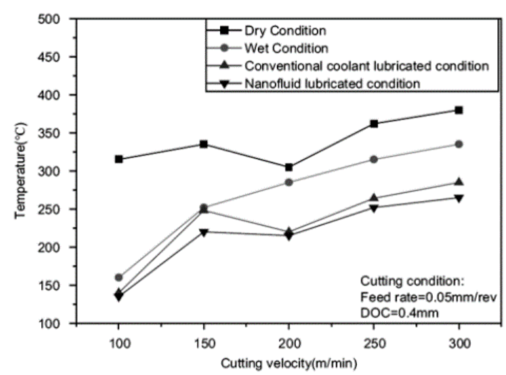

Fig. 3. Effect of nanofluids on the workpiece temperature

The Fig. 3, shows that the relation between the temperature drop between different machining processes under same conditions of cutting velocity. The result shows that most of the temperature drop occurs under nanofluids lubrication condition [28].

B. Difficulties of applying nanofluids in machining

Nanofluids differ with simple solid- liquid mixtures. Some special conditions in nanofluids are required, such as uniform and stable suspension, low clustering of particles, etc. To achieve these special conditions different ways are used. The main problem for preparing of nanofluids is its clustering [29].

For instance, to achieve the mentioned properties, changing in pH of solution suspension, using of surfactants, disperser, or vibrators can be used. Moreover, cost of nanoparticle and preventing them from sedimentation are two other issues that should take into account. High cost of nanoparticle, need for particular devices, clustering and sediment are negative aspects of nanofluids applications in metalworking operations [30].

7. Conclusion

In this paper, first of all, some of the alternatives for coolant oil like vegetable based cutting oil (Neem oil and water melon seed oil) and nanofluids were introduced and then, effect of those coolants on cutting parameters (surface roughness, tool-workpiece temperature, and environmental aspects) were reviewed. It has been established that environmental-friendly vegetable-based oils are potential than compared to petroleum-based mineral oils as cutting fluids. Life and cutting ability of the tool is improved to large extent. Cooling property of neem and water melon vegetable cutting fluids gave a performance in comparison with that of conventional soluble oil, as indicated by slight temperature differences on the values obtained. Friction between the tool and the work piece is reduced. Productivity of the machined products increases. Neem and water melon oil are environment friendly than petroleum oil.

Present analysis illustrate that using nanofluids and the type of nanoparticle and base fluid, size of nanoparticle and concentration of particles in base fluid influence on machining parameters too. Results show if they applied properly, due to change in lubrication trait, better heat transfer rate will be observed. As a conclusion, utilizing nanofluids as coolant and lubricant lead to lower tool temperature, tool wear, higher surface quality and less environmental dangers. However, high cost of nanoparticle, need for particular devices, clustering and sediment are negative aspects of nanofluids applications in metalworking operations. Better surface finish indicates that there is less friction and tool wear between tool and work piece in case of the usage

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