Physical properties of Nano based Bio-Oils as cutting fluids

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Abstract

The performance of any cutting fluid depends on its physical properties. A good cutting fluid should have high flash and fire point, so that it can withstand high temperature; resulted due to friction between tool-chip interface & tool-workpiece interface. Viscosity should not be high as cutting fluid will not carry away the heat and chip produced. It should not be low also as, the oil just flows from machining zone without doing its intended function, hence Viscosity should be optimum. Cutting fluid should have high specific heat so that heat absorption will be high and optimum Adhesiveness for good lubrication. The present paper discusses the physical properties of various bio-oils, SAE 20W40 (petroleum based oil), and compares the results measured with the addition of nano Graphite powder.

Keywords: Bio-Oils, Cutting fluids, Flash point, Fire point, Viscosity, Adhesiveness

Introduction

Cutting fluids are used to reduce the negative effects of the heat and friction on both tool and work piece. The cutting fluids produce three positive effects in the process heat removal, lubrication on the chip-tool interface and chip removal [1][2]. However, the advantages caused by the cutting fluids have been questioned lately, due to several negative effects they have caused in the environment and worker health. When inappropriately discharged, cutting fluids may damage soil and water resources, causing serious environmental impacts. On the shop floor, the machine operators may be affected by the negative effects of cutting fluids, such as skin and respiratory problems [2][9]. For these cases alternative solutions are developed to avoid environment and health. The use of vegetable oils allows high performance in machining combined with good environment compatibility could be achieved. Compared to mineral oil, vegetable oil can even enhance the cutting performance, extend tool life and improve the surface finish. Although, they have many environmental benefits, vegetable oils are more susceptible to degradation by oxidation or hydrolytic reactions [3][10].

A vegetable oil is a triglyceride extracted from a plant. Vegetable oils are classified in two types. They are edible and non-edible oils. Vegetables oils which are used for cooking purposes are called edible oils such as coconut oil, palm oil, palm kernel oil etc., are called as non-edible oils. Non-edible vegetable oils are technically and environmentally acceptable and easily available resource for bio-lubricants [11][12]. The non-edible oils have large scope to utilize them as metal working fluids. This makes to select both edible and non-edible oils such as Neem, Karanja, Sunflower and coconut as cutting fluids [5].

Experimental details

Selection of vegetable oils

Vegetable oils selected for the present study are Neem, Karanja oil, coconut oil and sunflower oil. Neem oil is a vegetable oil pressed from the fruits and seeds of the Neem tree, an evergreen tree which is native to the Indian subcontinent and has been introduced to many other areas in the tropics. It is the most important of the commercially available products of Neem for...
organic farming and medicines. Karanja oil is derived from the seeds of the Millettia pinnata tree, which is native to tropical and temperate Asia. Millettia pinnata, also known as Pongamia pinnata or Pongamia glabra, is common throughout Asia. Sunflower oil is the non-volatile oil compressed from the seeds of sunflower. Sunflower oil is commonly used in food as frying oil, and in cosmetic formulations as an emollient. Coconut oil, or copra oil, is an edible oil extracted from the kernel or meat of mature coconuts harvested from the coconut palm. In the present work, properties of different vegetable oils are experimentally determined. Vegetable oils used are Neem, sunflower, coconut, Karanja (Honge) and Neem oil (50% Neem & 50% Karanja) blend. The same vegetable oils with addition of Nano graphite powder are also used as Nano based bio-oils in the second stage experimentation.

Selection of Nano Powder

Graphite is a type of carbon, which has properties like High melting point. It contains layers of carbon atoms, these layers slide over each other easily due to the existence of weak forces between them which help graphite for easy sliding. The electrons present can move through the graphite, carrying charge from place to place and allowing graphite to conduct heat. Because of these characteristics graphite is used as solid lubricant.

Operational setup

Cleveland open cup tester

The Cleveland open-cup method is one of three main methods in chemistry for determining the flash point of the oils using a Cleveland open-cup apparatus, also known as a Cleveland open-cup tester. Using this test the flash and fire points of different cutting fluids were found out.

Saybolt viscometer

Saybolt viscometer is a device used to measure the viscosity of a fluid. The Saybolt viscometer control the heat of the fluid and the viscosity is the time it takes the fluid to fill a 60cc container.
temperature increases, the vapor pressure increases. As the vapor pressure increases, the concentration of vapor in the air increases. A certain concentration of vapor in the air is necessary to sustain combustion, and that concentration is different for each liquid. At flash point, a substance will ignite briefly; vapor might not be produced at a rate to sustain the fire. Figure 5 & Figure 6 shows the measured flash and fire point of different cutting fluids used in the present study. The flash point of sunflower oil is very high compared to other cutting fluids, next followed by coconut oil and Neem50% & Honge 50% blend oil.

The fire point is the temperature at which the vapor produced by that given fluid will continue to burn for at least 5 seconds after ignition by an open flame. Higher the fire point greater will be the resistance to ignite. Hence good cutting fluid should have higher fire point, so that it should not catch fire at drilling temperature. The fire point of sunflower oil is very high compared to other cutting fluids, next followed by coconut oil and Neem50% & Honge 50% blend oil. The flash and fire points of are calculated by using Cleveland’s apparatus. From the results obtained it is observed that the flash point of sunflower oil is very high compared to other cutting fluids, next followed by coconut oil and Neem50% & Honge 50% blend oil. The fire point of sunflower oil is very high compared to other cutting fluids, next followed by coconut oil and Neem50% & Honge 50% blend oil.

The flash and fire points of are calculated by using Cleveland’s apparatus. From the results obtained it is observed that sunflower oil, coconut oil and Neem50% & Honge 50% blend oil has flash and fire point compared to Petroleum based oil(SAE20W40) and Neem oil. Addition of graphite Nano powder has not much varied the flash and fire point of these oils. It is seen that increase in % addition of graphite powder from 2%, 4% and 6% both flash and fire point also increases slightly.

![Flash Point(C) vs Cutting Fluids](image1)

**Figure 5.** Flash point of various vegetable oils with, without addition of nano graphite powder and Petroleum based oil

![Fire point(°C) vs Cutting Fluids](image2)

**Figure 6.** Fire point of various vegetable oils with, without addition of nano graphite powder and Petroleum based oil

**Viscosity**

The viscosity of a fluid is a measure of its resistance to gradual deformation by shear stress or tensile stress or it refers to resistance to flow. A good cutting fluid should have optimum viscosity i.e. if it is high then oils does not carry away heat and chip from machining zone and it will stick the chip in the machining area effecting machining efficiency. If it is low then it will just pass away from machining zone without lubricating the tool and work piece. Viscosity of selected oils is measured by using saybolt viscometer and values obtained are tabulated in table 4.2. Since viscosity related to
motion of oils is important, dynamic viscosity plays an important role. From figure 7, it can be seen that sunflower oil has highest Dynamic Viscosity \((10.132 \times 10^{-3} \text{N-s/m}^2)\), next followed by Neem oil. Petroleum based oil and coconut oil has lowest Dynamic Viscosity; Whereas Neem50% & Honge 50% blend oil has optimum Dynamic Viscosity \((8.976 \times 10^{-3} \text{N-s/m}^2)\) compared to other oils, this indicates that the blend of 50%Neem 50% Honge has medium or optimum flow compared to other oils and capable of retaining a layer between drill bit, workpiece and chip sliding over the flute indicating that it is good lubricant. Addition of graphite powder has not improved the viscosity, but instead it reduces the viscosity than optimum required when added with increasing percentage from 2%, 4% and 6%.

![Dynamic Viscosity of various vegetable oils with, without addition of nano graphite powder and Petroleum based oil](image)

**Figure 7.** Dynamic Viscosity of various vegetable oils with, without addition of nano graphite powder and Petroleum based oil

### Specific Heat

The specific heat is the amount of heat per unit mass required to raise the temperature by one degree Celsius. A good cutting fluid should have high specific heat, so that it can absorb max heat from the machining zone to rise its temperature instead of allowing heat to transfer to the tool and work piece. Figure 8 shows the graph of specific heat measured for different cutting fluids. From the table, it can be seen that sunflower has highest value followed by blend of 50%Neem 50%Honge and petroleum oil. This shows that sunflower oil and blend of 50%Neem 50%Honge oil are capable of absorbing higher heat from the machining zone or acts as good coolant compared to others oils used. Addition of graphite powder has not improved the Specific Heat of cutting fluids but instead it can be seen from the table that increasing the addition of graphite from to 2%, 4% and 6%, specific heat is getting decreased compared to pure oil.

![Specific heat of various vegetable oils with, without addition of nano graphite powder and Petroleum based oil](image)

**Figure 8.** Specific heat of various vegetable oils with, without addition of nano graphite powder and Petroleum based oil

### Adhesiveness

This property of cutting fluid refers to ability of fluid to stick to the surface of work and tool during machining and
maintain separating layer between both elements, so that friction is less. Adhesiveness should not be too high as the fluid will stick to surface along with chips formed. This reduces the life of the tool and machining efficiency. If it is too low then the fluid cannot separate the elements during machining resulting in higher friction and reduction to tool life. A good cutting fluid should have optimum or moderate value of Adhesiveness, so that both the above problems can be overcome. Method used for this is as shown in the Figure 4.2 (Michalski & Desobry, 1998). Figure 9 shows variation of adhesiveness with cutting fluids. Neem has highest Adhesiveness with value of 668 g/m², least is 315 g/m² for coconut oil 319 g/m² for sunflower oil and Petroleum based oil. The optimum value is for blend of 50% Neem 50% Honge with the value of 343 g/m². This shows that 50% Neem 50% Honge is best blend as it separates the machining elements and carries away the heat. Addition of graphite to these oils with varying percentage i.e. 2%, 4% and 6% will reduce the Adhesiveness as shown in the figure 9 this may be because graphite is very softness and provides better sliding properties due to which it is used as solid lubricant.

Figure 9. Graph showing Adhesiveness measured for different cutting fluids

Conclusions

The performance of cutting fluid depends on the physical properties. The vegetable based cutting fluids used in the present work are sunflower oil, coconut oil, Neem oil, SAE20W40 (petroleum based oil) and blend of 50% Neem-50% Honge oil. Good cutting fluid should have high flash and fire point, high specific heat, optimum dynamic viscosity and optimum Adhesiveness. From the results obtained, it can be concluded that sunflower oil and blend of 50% Neem-50% Honge oil has the required characteristics of good cutting fluid.

Physical properties of these oils were measured again with the addition of varying percentage of graphite powder i.e. 2%, 4% and 8% to sunflower oil, coconut oil, Neem oil and blend of 50% Neem-50% Honge oil. From the results obtained it can be concluded that addition of graphite has not improved the physical properties (as only small variations are observed in the measured values)

References

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