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PERFORMANCE EVALUATION OF CUTTING FLUID DERIVED FROM BLENDS OF AVOCADO AND NEEM SEEDS

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A B S T R A C T

Researches are underway to develop new bio-based cutting fluids as an alternative to petroleum-based oils characterized by machinist and environmental challenges. In this work, cutting fluid was developed from Avogadro and Neem seed. The performance of the extract and the blended fluid was then evaluated by comparing it to a conventional cutting fluid (control) to ascertain its ability to function effectively as a coolant during turning operations on a lathe machine. Data on cooling characteristics, chip thickness, surface finish, and corrosion were collected and analyzed. The thickness of the collected chips was evaluated. Temperature fluctuations during the cutting process were also measured with an infrared thermometer. The machining process was performed at three different cutting speeds (35, 60, and 150 rpm), and the feed rate and cutting depth (1.5 mm) were constant throughout the process. The result obtained from the developed fluids were compared to that of the conventional cutting fluid and dry cutting; and the temperature, surface finish, and chip thickness were analyzed. The average temperature of the workpiece for formulated fluid was 63.33°C, that of the extract 52.00, 50.46 °C, respectively, and dry cutting 83.1°C. The results were closely related to that of the conventional fluid, but the vegetable extract shows better results in conducting heat away from the cutting region. The formulated fluid gave an average high chip thickness of 1.41mm while that of the dry, extract, and conventional cutting fluid was found to be 0.85,1.02, and 1.08 and 1.01mm for avocado and neem respectively. The high chip thickness of the formulated fluid is probably due to its better lubricating ability which allows easier and deep penetration of cutting tools. The viscosity of the formulated fluid was found to be 28 poise at 27°C. The formulated cutting fluid possesses the properties required of cutting fluid at both higher and lower temperatures. Also, the fluid has a good ability to inhibit corrosion while the vegetable extract poses a sign of corrosion.

Keywords:Cutting fluid, Neem, Avocado, temperature

1. Introduction

The growing demand for biodegradable fluids has opened up ways to use vegetable oils as an alternative to petroleum-based oils, especially in machining processes (Singh, 2008). Vegetable oils are a very attractive alternative to petroleum-based oils because they are environmentally friendly, renewable, less toxic, and highly biodegradable (Dinda *et al.,* 2008). Much research is underway to develop new bio-based cutting fluids made from a variety of vegetable oils available worldwide.

Cutting fluids are classified into three main groups, these are:
1. Neat cutting oil;
2. Water-soluble fluids; and
3. Gases.

The water-soluble fluids can be classified as emulsifiable oils (soluble oils), chemical (synthetic) fluids, or semi-chemical (semisynthetic) fluids. The cooling property of water when combined with the lubricating property of oil serves as an advantage when emulsion cutting fluid is used in the machining process (El Baradie, 1996).

The cutting fluid used in the machining process has four main characteristics:

1. For lubrication during low-speed cutting
2. Cooling at high cutting speed
3. To support chip evacuation from the cutting zone
4. Protects machine tools and workpieces from corrosion.

By using the cutting fluid as a coolant or lubricant, the heat generated in the cutting zone during machining can be reduced, but it is only effective as a lubricant at low speeds. The ineffectiveness of the fluid as a lubricant is primarily due to the inability of the cutting speed to penetrate the actual cutting zone between the insert and tool interface (Hemant & Mahendra 2014). However, the cooling effect and lubrication effect of the cutting fluid interact with each other, and this effect decreases as the cutting speed increases. Cutting fluids based on mineral oils are used because of their low costs and chemical stability (Kishor&Ravi 2017). Chemically based or formulated cutting fluids are used based on the present advantage less of effects to the environment and the operating personnel (operator) compare to the environmentally friendly vegetable-based cutting fluids (Kishor&Ravi, 2017).

The neem tree (*Azadirachta indica Juss*.) is local to the tropical and semi-tropical area and began in Europe and was later domesticated in Asia. It is notablyobserved in India and Indonesia (Lew, 2012). It is likewise ubiquitous in Northern Nigeria, and prettyobserved in Western Nigeria, in whichit's far popularly known as Dogon Yaro. It is a tree withinside the mahogany's circle of relatives with vastdarkish stem and broadlyunfold branches. It grows above 20m – 25m and produces evergreen leaves with white aromaticvegetation and fruits. It is likewise drought resistant. All elements of the neem tree, the leaves, twigs, and the nuts in which oil is extracted are used industrially and for medicinal causes as a coolant. Neem oil is normallycharacterized with mild to darkish brown color, sour and has as an alternativesturdysmellthis isstatedto mix the odors of peanut and garlic (Ademo *et al.,* 2016).

Avocado (Persea Americana Mill.) is a member of the Lauraceae family. Although avocado trees are local to Central America, they may beadditionallybroadlydispensed in tropical and subtropical countries (Dabas *et al.,* 2013). Anatomically, the avocado fruit may beprominent in 3 regions - the innermost seed that constitutes 20% of the fruit, the pulp protecting the principal portion (65%), and the outermost peel (15%) (Costagli & Betti, 2015). Popularly recognized as "vegetable butter" or "butter pear", the fruit incorporates a substantial quantity of triglycerides (TGs) at the side of the excessivecontent material of unsaturated fatty acids. Unlike oil extracted from different fruits, the oil from avocado fruit is regularly extracted from the mature fruit flesh (Barros *et al.,* 2016). Avocado oil has a mess of packageswhich include a culinary oil and as a component in healthcare products, cosmetics, prescribed drugs, and nutraceuticals (Woolf *et al.,* 2008).

The performance of these two oils (Avocado and Neem) is similar such as in areas of surface finish, chip thickness, and temperature. Hence, the issue is the environmental effects and hazards to workers and also the need to develop safe and efficient metalworking fluid which is friendly to the environment. The concern of this investigation is to use avocado seed and Neem seed extract to develop a vegetable-based cutting fluid because of the seeds' availability and high fatty acid content. The product of this investigation was tested in turning operations using mild steel to verify its performance.

Ademoh *et al.* 2016, investigated the comparative performance of soluble oil, Neem oil, and watermelon oils for application as Cutting fluids in a turning operation using Mild steel and spindle speeds of 250 rpm, 710 rpm, and 180 rpm; depth of cut of 1 mm, 0.5 mm and 0.75 mm were used respectively, automatic feed rate and an ambient temperature of 34°C. Machining results show that the temperature achieved with 100% oil-produced watermelon seed oil (54.66 ℃) and conventional cutting oil (53 ℃) is the temperature achieved during drying. Machining at 50 ℃ shows that it does not work well as a lubricant for metal cutting operations because it exceeds. Treatment with 25% neem seed oil and 75% water emulsion reached a minimum temperature of 37.33 ℃. All oil-water emulsion ratios are effective as coolants and are comparable to conventional cutting oils tested.

Eziwhuo & Joseph 2020, in this work, oil was extracted from non-edible vegetable seeds (Cocoa seeds CS, Soursop seed SS, and blend of 50%CSO and 50%SSO). The machining output parameters (Interfacial Temperature, Surface Roughness, and Chip thickness) were used for comparison with vegetable-based cutting fluids and mineral cutting fluids. The results showed that an increase in speed decreased the surface roughness of AISI 1020 steel; and the least surface roughness-value and surface temperature value was 1.7 μm, 48.9 ℃ obtained at the spindle speed of 200 rpm for blended of 50%CSO and 50%SSO) oil-based fluids. The NVBCFs of different formulations all showed good lubricant properties which compared favorably with the commercial cutting fluids (CCFs). The non-edible vegetable seeds base cutting fluids (NVSBCFs) formulation that showed the best surface cooling characteristics, lowest roughness, and chip thickness formation was blended of 50%CSO and 50%SSO) cutting fluids, even better than the commercial cutting fluid (CCFs).

Yakubu & Bello 2015, investigated neem seed oil to determine its suitability as a cutting fluid. So, the neem seed oil was used as a cutting fluid to machine aluminum manganese alloy 3003 in a center lathe machine under the following machining (turning) conditions: Spindle Speed (V) was 250, 355, and 500 rpm respectively; depth of cut (d) was 0.5mm, 1.0mm and 1.5mm respectively; the feed rate (f) was 1.05mm/rev, 1.52 mm/rev and 2.10 mm/rev respectively. Carbide tool inserts grade SNMG 120408-QM H13A was used. The results of the neem seed oil in terms of the surface roughness and tool wear were compared with that of the soluble oil and 'dry' machining. Based on the obtained results, the neem oil reduced the surface roughness by 39% and 22% when compared to soluble oil and dry machining respectively. The soluble oil reduced the flank tool wear by 24% compared to dry turning. The lowest surface roughness was obtained when the V = 500 rpm, f = 1.05 rev/mm and d = 0.5 mm in comparison with soluble oil and dry machining. It has been established from the results that the neem seed oil gave the lowest flank wear at a spindle speed of 250 rpm, feed rate of 1.05mm/rev, and depth of cut of 0.5 mm as compared to dry and soluble oil machining. The neem seed oil reduced the flank wear by about 72% and 56% as compared to dry turning and soluble oil cutting respectively, while the soluble oil reduced the flank wear by 36% as compared to dry turning. Therefore, the neem seed oil is not only suitable for cutting fluid, but it is more effective as a cutting fluid than the soluble oil as a cutting fluid.

Osayi *et al*. 2021, in this study, rubber seed oil was used to formulate oil-in-water emulsion cutting fluid. A full factorial design was used for the formulation of the oil-in-water emulsion cutting fluid. The optimal process parameters obtained were used for the formulation of the novel cutting fluid and the cutting fluid was characterized. Box-Behnken design was used for the turning operation and the performance of the rubber seed oil cutting fluid was compared with mineral oil. The input parameters were cutting speed, feed rate, and depth of cut, while the responses were surface roughness and cutting temperature. Coated carbide insert was used as a cutting tool. The ANOVA results show that the feed rate had the most significant effect on the surface roughness and cutting temperature followed by the cutting speed and depth of cut during the turning process. It was observed that the rubber seed oil-based cutting fluid reduced surface roughness and cutting temperature by 9.79% and 1.66% respectively and therefore, it can be concluded that the rubber seed oil-based cutting fluid performed better than the mineral oil in turning of mild steel.

Ezekiel & Aminu 2018, study investigated the effects of using neem oil as a base in cutting fluid for machining operations in Adamawa state polytechnic. some aspects of the turning process on mild steel using the HSS cutting tool at a variety of spindle speeds, feed rate, and constant lengths of cut were observed using neem seed oil, soluble oil, and straight oil in comparison. The findings of this study serve as the basis for concluding that temperature reduction was best obtained using neem oil as base cutting fluid than soluble oil and straight oil whereas minimum surface roughness and best surface quality was obtained using neem seed oil as cutting fluid as compared to straight oil and soluble oil cutting fluid in turning operation of mild steel workpiece using HSS cutting tool. The least surface roughness was achieved at a spindle speed of 540 rpm using neem seed oil. It was the most effective in reducing surface roughness as spindle speed increased. Neem seed oil had the best surface quality at feed rates lower than 0.2 mm/rev, while the highest surface roughness was observed at a feed rate of 1.0 mm/rev and spindle speed of 58 rpm during turning operation.

From the above literature, research concerning cutting fluids in machining operations, the relationship between the cutting speed, a constant and material type which affect the performance of the cutting tools, has not been completely investigated at the same time. Therefore, this present work showed experimental results of the performance of these two oils (Avocado and Neem) in surface finish, chip thickness, and temperature.

2. Materials and Methods

2.1 Materials

2.1.1 Cutting Fluid Materials

The materials used for the formulation of the cutting fluid in this study include neem oil, avocado oil, and additives (emulsifier, washing soap, phenol, sulphur).

2.1.2 Turning Process Materials and Equipment

The material for the turning operations is a mild steel rod of 400 mm length and 16 mm diameter. The equipment used includes a lathe machine, cutting tool, infrared thermometer, and surface roughness tester.

2.2 Methods

2.2.1 Physicochemical Properties of the Neem and Avocado Oil

The physicochemical properties that were determined include: kinematics viscosity (ASTM D 445), acid value (ASTM D664), flash point (ASTM D 92), pour point (ASTM D 97). The specific gravity, saponification value, fatty acid composition, and iodine value were determined using the expressions by Akpan *et al.*, 2006. The pH value was determined using LABTECH 3450 digital pH meter.

2.2.2 Formulation of the Cutting Fluid Oil

The oil sample used in this work was prepared into cutting fluid using the suggestions given by earlier researchers in this field (Ibahadode, 2001 and Chapman, 2002). In preparing the sample of cutting fluid, 500 ml of vegetable oil was measured (using a 1-liter measuring beaker) and mixed with water in oil to water ratio of 1: 10 (Chapman, 2002). This mixture was thereafter blended with 10% vol/vol washing soap, 5% vol/vol phenol, 5% vol/vol sulphur, all at room temperature as shown in Table 1.

Table 1 - Blending ratio

Material	Function	Qty (vol/vol)
Mixed oil	Base oil	80
Washing soap	Emulsifier	10
Phenol	Disinfectant	5
Sulphur	Extreme pressure agent	5

2.2.3 Characterization of the formulated Cutting Fluid

the fresh formulated cutting fluid was characterized based on kinematic viscosity, flash point, pour point, pH, and corrosion, which were carried out by ASTM standards. The kinematic viscosity of the formulated cutting fluid was carried out according to ASTM D 445. The flashpoint of the formulated cutting fluid was carried out according to ASTM D 92. The pour point of the formulated cutting fluid was carried out according to ASTM D 97. The pH value of the formulated cutting fluid was measured by using LABTECH 3450 digital pH meter. A corrosion test of the formulated cutting fluid was done by ASTM D 4627. The corrosion test was done using 10 g of mild steel chip washed in acetone and dried, placed on a piece of filter paper in a Petri dish. The chips were evenly spaced around the filter paper and were prevented from contacting one another, then placed under the sun for 2 hours. The chips were then soaked in 2 ml of the test extract and the formulated fluid, then chips were left in the covered Petri dish for 2 hours. At the end of the 2 hours, the mild steel chip is discarded and the filter paper is rinsed in acetone. The corrosion grade of the cutting fluid is measured by observing how many spots appear on the filter paper surface.

2.2.4 Determination of Surface Roughness

A surface roughness tester was used to measure the surface finish of the workpiece machined with the vegetable extract, formulated fluid, conventional fluid, and under dry machining conditions. Three measurements were taken at different points along the surface of the workpiece and the average value was recorded for analysis.

2.2.5 Determination of Cutting Temperature

The temperature of the cutting area was measured with an infrared thermometer. The beam was radiated at the cutting area (interface point between the cutting tool and the part for about 2 seconds), during which the measured temperature value was displayed on the screen. Three measurements are made at different points along the line. machining details of each test and the average temperature used for the analysis.

3. Results and Discussion

3.1 Properties of the formulated Cutting Fluid

Table 2 below shows the result obtained from the test of various properties of formulated cutting fluid.

Table 2: Properties of the formulated Cutting Fluid

Property	Formulated cutting fluid
Specific gravity	0.926
Flashpoint, °C	334
Pour point, °C	-39
Free fatty acid, wt%	1.692
Saponification value, Mg/KOH/g	162.5
Iodine value, mg/g	59.1
Acidic value, Mg/KOH/g	7.55
Appearance	Transparent

The specific gravity of formulated oil (0.926) was the same as that of rubber oil (0.92) (Osayi *et al.*, 2021), and the lower the value, the better the property, since heavy oil does not penetrate lightly. The acidic value of the formulated oil (7.55 mg KOH/g) in comparison to that of rubber oil (7.29) [Osayi *et al.*, 2021] are similar. Acidic fluid promotes emulsification and higher corrosion tendencies thereby corroding the workpiece. The saponification value of the formulated oil (162.5) was similar to that of rubber seed (163.60) mg KOH/g) (Osayi *et al.*, 2021) and that of neem oil (166 mg KOH/g) [Chauhan and Chhibber, 2013]. The formulated oil has an iodine value 59.1 mg/g) and was similar to that of palm oil (54.24) [Da Silva *et al.*, 2006]. The flashpoint value is 334 °C, the high flashpoint of formulated oil indicates that it is safe to handle.

3.2 Effect of Corrosion

The result for the corrosion test obtained shows that for the formulated fluid, there was no trace of corrosion spot on the filter paper meaning that its effect on the metal is corrosion-free. For the extracted and conventional fluid, traces of corrosion spots were seen on the filter paper indicating its corrosion effect on the metal in contact.

3.3 Effects on Chip Formation/Thickness

Table 3 below is the result obtained from the test carried out.

Table 3 - Results for chip thickness for 60rpm

Specimen	Chip thickness (60 rpm) mm
Dry operation	0.85
Avocado oil	1.08
Neem oil	1.01
Formulated cutting fluid	1.41
Conventional fluid	1.02

The conventional cutting fluids, neem oil, avocado oil, and formulated oil showed a relatively high chip thickness than that of the dry cutting chips. Thus, high chip thickness is associated with a low coefficient of friction. This means that the fluids help in reducing friction during cutting/machining.

3.4 Effect of Viscosity

The viscosity test of the developed fluid was carried out under two different temperatures with two spindle sizes as shown in Table 4.

Table 4 - Results of viscosity test

Fluid	Temp. °C	Spindle speed (rpm)	Viscometer reading (cp)
Avocado oil	27	2	28
Neem oil	27	2	27
Formulated fluid	60	3	25
Conventional fluid	60	3	29

The viscosity of the formulated fluid was analyzed in comparison to that of the conventional fluid. Viscosity accounts for the effectiveness of a liquid fluid to perform lubrication and cooling at the same time developed. High viscous fluids produce thick film lubrication and low cooling rate and vice-visa, meaning for a cutting fluid low viscosity are more effective in terms of lubrication, cooling property, and chip removal for workpiece/tool interface. From the result obtained, the formulated fluid can perform at any temperature be high or low without causing any film on the workpiece.

3.5 Effects on temperature variation

Using three different fluid and dry operations, it can be seen that increase in speed results in to increase in temperature and depth of cut. This is because cutting forces decrease with speed and since the quantity of heat produced is the product of force and velocity, it follows that more heat is generated with an increase in cutting speed. From the data obtained as shown in Fig. 1, the formulated cutting fluid has a higher cooling property than the avocado and neem, but the formulated fluid tends to perform cut better at low cutting speed this is because of its lubricating property.

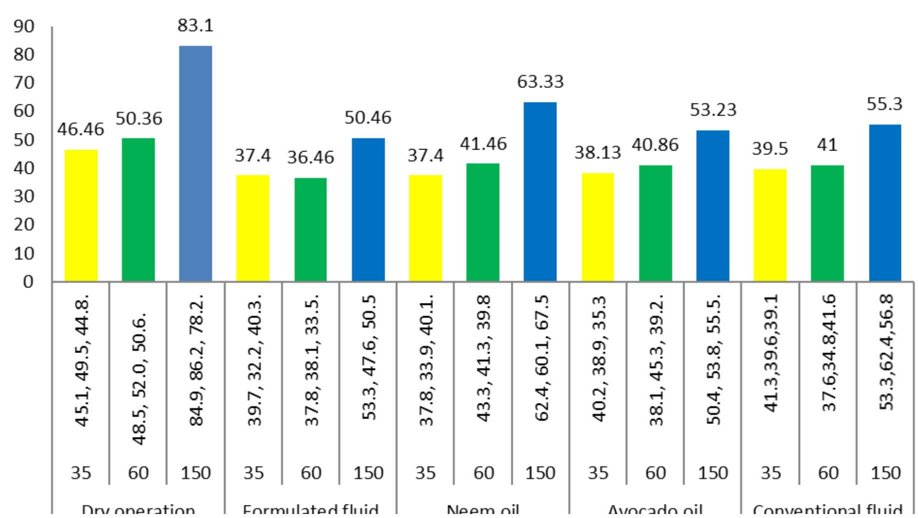

Fig. 1 - Temperature variation.

From the result obtained, the correlation between speed and temperature implies that as the speed increases the temperature also increases. Therefore, the result shows that there is a strong correlation between speed and temperature which gives 83% efficiency

3.6 Effects of fluids on surface roughness

Fig. 2 below represents the relationship for the values obtained from the test carried out for the surface roughness.

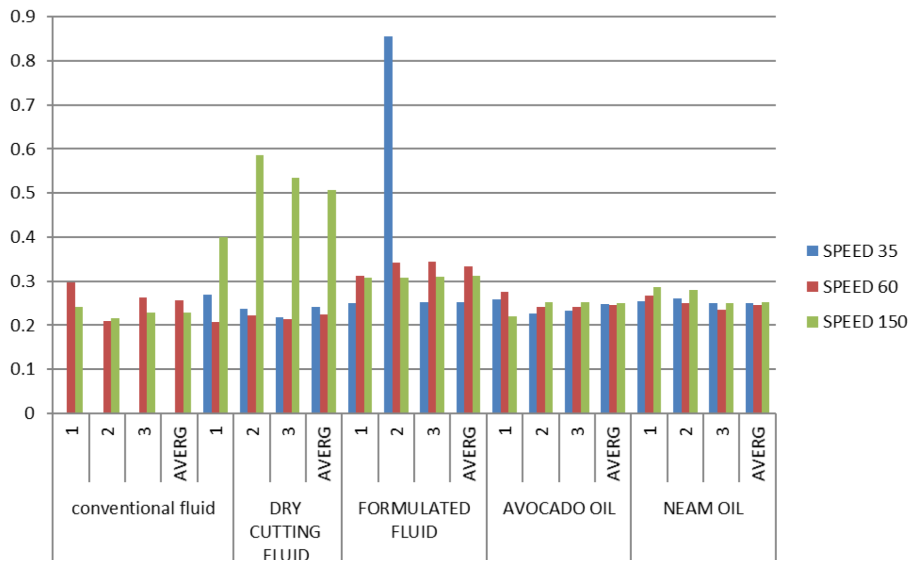

Fig. 2 - Surface roughness.

It was observed that as the speed increases, the surface roughness reduces due to reduction in friction between the tool and the machined surface, high spindle speed reduce forces and vibration of the turning operation, giving the workpiece a better surface finish. Meaning that speed is one of the major attributing factors to surface roughness.

4. Conclusions

This research has aided in establishing the fact that environmentally friendly vegetable-based fluid can successfully replace the conventional petroleum-based fluid as cutting fluid. From the discussion made, the following conclusion can be drawn.

1. Oils were successfully extracted from avocado and neem seed.
2. Oils extracted were characterized, average temperature (using different speeds 35, 60, and 150 rpm). Avocado 47.40 ℃, Neem 44.10 ℃).
3. Cutting fluid was successfully formulated using the extracts oil.
4. The cutting fluid was evaluated after turning operation on mild steel, it shows that pH = 7.55, viscosity = 6.88, no corrosion spot, and the average temperature is 42.5 ℃ (using different speeds 35, 60, and 150 rpm).

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