



## COMPARATIVE ANALYSIS OF CUTTING FLUIDS DEVELOPED FROM GROUNDNUT OIL AND USED ENGINE OIL FOR MACHINING OPERATION

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### ARTICLE INFORMATION ABSTRACT

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This research concentrates on the development of cutting fluid from spent engine oil used in motor vehicles (used engine oil) and groundnut oil, for the purpose of cooling the heat generated in the cutting zone during metal work. Cutting fluid are widely used in machining process such as turning, milling, grinding and forming manufacturing process. Four different soluble oil were developed using locally sourced material and applied as cutting fluids for turning operation in a lathe machine. Sample A comprises groundnut oil, emulsifying wax, potassium dichromate, 2-aphtol, Sulphur, Soap. Sample B comprises Groundnut oil, Liquid paraffin, Potassium dichromate, 2-Naphtol, Sulphur, Soap. Sample C comprises of Used Engine oil, Emulsifying wax, potassium dichromate, 2-Naphtol, Sulphur, Soap. Sample D comprises of used engine oil, liquid paraffin, potassium dichromate, 2-Naphtol, Sulphur soap. Determination of temperature, viscosity, PH values and percentage of free fatty acid (%FFA) were conducted on these samples. Viscosity and pH values of the samples were measured using Brookfield Synchro-electric Viscometer and pH meter, respectively. A straight-turning operation was carried out on a bar (workpiece) of 4mm diameter, using a lathe machine at a feed rate of 2 mm/min at a turning speed ranging from 58 to 370rpm. Using dry cutting, the cutting zone generated a temperature of 73°C. When applying the developed cutting fluids directly at the tool tip-work piece point of contact, determination of their ability to dissipate heat away from the cutting zone, using a thermocouple was conducted. It was observed that the turning operation conducted with sample D serving as cutting fluid (with a cutting zone temperature of 17.0°C and viscosity of 0.365) dissipated more heat (56°C) away from the cutting zone when compared to samples A, B and C, having temperature and viscosity of 32°C, 28°C, 20°C and 0.02, 0.235, 0.155 Nsm<sup>-2</sup> respectively. Sample D has the lowest pH value of 3.78 making it more acidic and susceptible to corrosion. In conclusion, all the samples can be used for cutting fluid.

### 1.0 Introduction

Metalworking operation involves generation of heat due to friction between the tool and the work piece. The surrounding air alone is rather a poor coolant for metalworking operations because the rate of heat transfer is low. Ambient-air cooling is adequate for light metalworking processes such as metal cutting with periods of rest in between them (Tschätsch and Reichelt, 2009).

However, for heavy metalworking operations, more heat is produced which cannot be removed by mere ambient air. It is not reasonable to introduce long idle periods into the cycle time to allow the air-cooling of the tool when the heat removal can instead be accomplished with a flood of liquid, which can keep up with the heat generation (OSHA, 1999). The primary

functions of cutting fluid are: to cool the cutting tool, workpiece and chips; to reduce friction at the contact surface; and to reduce adhesion of the cutting tool and workpiece or chips at the contact surfaces (Ávila and Abrão, 2001). Moreover, the cutting fluid flushes away chips from the cutting zone and protects the workpiece and tool from excessive heat (Nwadinobi and Okoli, 2018). Thus, in machining operations the use of cutting fluid is inescapable. This incessant need prompts the desire to explore a new type of cutting fluid from cheap locally available materials. Tang et al. (2021) conducted a review on biological-stability of water based cutting fluids. In their research, cutting fluids were classified in accordance with their compositions into oil-based and water-based cutting fluids. It was reported that oil-based cutting fluid has high biological stability but insufficient cooling performance. In order to address this limitation, the present research looks at alternative cutting fluid from used engine oil (recycled spent engine oil that is used in motor vehicle) and groundnut oil. Four different types of cutting fluids will be developed based on the additives, hence, a comparative analysis will be carried out to measure the performance of the newly developed cutting fluids.

## 2.0 Materials and Method

### 2.1 Materials

The cutting fluid was prepared from used engine oil, groundnut oil, Emulsifying wax, soap, potassium dichromate, 2-Naphtol and sulphur. Four different samples were made, samples A, B, C, D. The percentage of oil (used engine oil and groundnut oil) is 90% by volumes of the prepared cutting fluid (Akii, 2001). The rest of the constituents (Emulsifying wax, soap, potassium dichromate, 2-Naphtol and sulphur) take the remaining 10%. In preparing a sample of cutting fluid, 1350 cm<sup>3</sup> of mineral oil was used. According to Nwadinobi and Okoli (2018), the constituents of the cutting fluids with their respective mass are presented in Table 1.

**Table 1:** Mass of Cutting Fluids Constituents

Sample	Cutting Fluids Constituents	Quantity in Grams (g)
A	Emulsifying wax	102.15
	Groundnut oil	1.35
	Potassium dichromate	1.00
	2-naphthol	1.00
	Sulphur	0.67
	Soap	120.15
B	Groundnut oil	1.35
	Paraffin liquid	120.15
	Potassium dichromate	1.00
	2-Naphtol	1.00
	Sulphur	0.67
	Soap	120.15
C	Used engine oil	1.35
	Emulsifying wax	120.15
	Potassium dichromate	1.00
	2-Naphtol	1.00
	Sulphur	0.67
	Soap	120.15

D	Used engine oil	1.35
	Liquid paraffin	120.15
	Potassium dichromate	1.00
	2-naphtol	1.00
	Sulphur	0.67
	Soap	120.15

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In addition to the materials above, in accordance with the work of Rasak et al. (2022), ethanol was used to dissolve the 2-Naphtol and then water, to dissolve potassium dichromate, and soap. Also, a high-speed steel cutting tool and a bar of a circular cross-section of 0.02 mm diameter were used.

## 2.2 Methods

The materials were weighed as required, 1.35g of used engine oil (Table 1) was poured into a beaker together with the emulsifying wax. With a stirrer in place and a thermometer clamped into the beaker, its content was heated on a kerosene stove. When the wax had totally melted at about 70 °C, the content of the beaker was thoroughly stirred for 20 minutes as prescribed by Nwadinobi and Okoli (2018) and the heating was stopped. At this temperature, its encounter with water and other similar liquids gives a frying sound.

Sequentially, one after the other, dissolved potassium dichromate and 2-Naphtol were poured into the beaker when the temperature of its content was about 60 °C or less potassium dichromate dissolves readily in water and 2-Naphtol in ethanol. Thorough stirring was done for each of the additions, a required quantity of sulphur powder was then added regarding the variations of 0.02%, 0.05%, 0.07% and 4% and a final stirring was done to obtain an oil blend for the respective variations.

In agreement with the work of Rasak et al. (2022), the emulsion was formed by pouring the soap solution into the oil, and not the other way around to form the required emulsion and viscosity. This was done at room temperature, by pouring the soap into the beaker of measured oil; stirring was done gently until a thorough mixture was obtained.

### 2.2.1 Weighing

The weighing was done using a high precision chemical balance (electronic precision chemical balance Model ADOI) with a capacity of 3000g and 0.1g sensitivity. Each of the materials was weighed separately in its respective percentage in grams.

### 2.2.2 Performance Test Methods

The major test parameter used to investigate the performance of each of the developed cutting fluids was temperature, the determinant being a measure of the ability of the cutting tool to conduct heat away from the work zone during the machining operation. In addition, the acidity and viscosity of the developed cutting fluids were also determined.

### 2.2.3 Temperature Measurement

ASTM E618-07 was used to evaluate the ability of each sample fluid to conduct heat away from the work zone, a bar of circular cross-section (0.04 m in diameter) was mounted on a three-jaw chuck of a lathe machine, and a straight straight-turning operation was carried out on the

bar using a feed rate of 2 mm/min for five minutes while applying the cutting fluid directly at the tool tip-work piece point of contact. The tool used was one with a positive rake; a new one was used for another sample, but with the same original tool tip ground configuration. The cutting speed was varied from 58 rpm to 370 (Nwadinobi and Okoli, 2018). The cutting fluid was applied with the aid of a coolant delivery system built into the lathe machine. A temperature indicator (thermocouple) made of copper and Constantine wire was used to measure the temperature right at the point where the tooltip made contact with the workpiece during chip removal. The reference junction of the thermocouple was always kept at 0 °C by constant monitoring and the addition of ice at 0 °C to the junction. The temperature reading at this point (which was read from the thermocouple as electric voltage) was noted and recorded and the procedure was repeated for all samples at the specific cutting speeds. The pH value, a measure of hydrogen concentration in the fluid, was obtained by using a pH-meter using a buffer solution of pH 7.0. The pH value was displayed on a digital device. According to Sui'i et al, (2023), the acidic value was calculated from equation 1;

$$FFA \% = \frac{ml\ of\ alkali \times N \times 10}{10(\text{weight of sample } g)} \quad (1)$$

Where, FFA % = percentage of free fatty acid

N = normality of alkali

ml of alkali = 165 ml

Samples B, C, D and E have the MI values 28 ml, 47 ml, 19 ml and 278 ml respectively. Therefore, the pH values are shown in Table 2.

### 3.0 Results and Discussion

From the results obtained, dry cutting has the highest temperature value of 73. Using sample D cutting fluid, having a cutting zone temperature of 17°C from Table 2, heat dissipated from the zone was 56°C.

**Table 2:** Sample Properties

S/No.	Sample	Viscosity	pH Value	Measured Temperature °C at cutting speed of 53-180 rpm	Measured Temperature °C at cutting speed of 180-373 rpm	Percentage of Free Fatty Acid (FFA%)
1.	A	0.020	08.54	20	32	13.65
2.	B	0.235	07.03	16	28	5.572
3.	C	0.155	10.24	9.0	20	9.353
4.	D	0.365	7.54	6.0	17.0	3.780
5.	E	0.026	7.05	8.0	19.0	55.72
6.	F	-	-	24	26	-

Table 2 shows the properties and behaviour of the samples under different working conditions. It could be observed that samples A, B, C and D which are mineral oil with emulsifying wax, mineral oil with liquid paraffin and the control cutting fluid respectively; had the ability to conduct away heat from the work zone at a lower cutting speed below (180 rpm). However, at cutting speeds greater than 180 rpm, sample D outweighed other samples in temperature lowering at the work zone. This result agrees with the work of Nwadinobi I and Okoli (2018).

Thus, it is fair to say that sample B had the same wettability at lower cutting speed. But its better perceived thermal stability due to its higher viscosity at higher temperatures due to the raised cutting speed, this may have accounted for the higher stability of sample D to cool the work zone than every other sample. Though it would have been a reasonable conclusion to exalt sample D over every other sample at this stage, it nonetheless has a higher viscosity than all other samples. This has some implications; it will not be able to penetrate rapidly to the tool chip interphase where maximum working temperature does occur (Rasak et al., 2022). Also, a fluid with a higher ability to conduct heat away from the work zone will promote the softening effect of the workpiece material caused by the heat, with this the metal keeps its resistance at higher levels than when a cutting fluid with a lower cooling ability is used (Rasak et al., 2022). The acid value of the oil gives a measure of how corrosive the cutting fluid developed from it could be to the workpiece, especially if it is mild steel. The very low acid values of samples B, C, and D put them forward ahead of others for use in machining operations involving mild steel. The high acid value of sample D may have been responsible for its highest translucent nature above other samples. A high acid value promotes emulsification with higher corrosion tendencies.

#### 4. Conclusion

On the basis of the experiments carried out on the various samples of oils the following conclusions are made:

- (i) All the samples can be used as cutting fluid because their performances show that they can remove heat during machining operation.
- (ii) The pH values of samples A, B, and C which are 13.65, 5.572, and 9.353 respectively, have the least tendency to corrode the work piece (mild steel) compared to sample D 3.781.
- (iii) Sample D removed heat (56°C) away from the cutting zone more than the other samples under the same conditions.

#### Reference

Akii, AO. 2001. Introduction to Manufacturing Technology. Ambik Publishers, University Press, Ibadan.

ASTM E618-07. 2018. Standard Test Method for Evaluating Metals using an Automatic Screws/Bars. ASTM International.

Ávila, RF. and Abrão, AM. 2001. The effect of cutting fluids on the machining of hardened AISI 4340 steels. Journal of Materials Processing Technology, (119)1: 21-26.

Kazeem, RA., Fadare, DA., Ikumapayi, OM., Azeez, TM. and Adediran, AA. 2022. Development of bio-cutting fluid (*Cirtulus lanatus*) and its performance assessment on the machining of AISI 1520 using taguchi technique and grey relational analysis. Biointerface research in applied chemistry. Platinum Open Access Journal, 12(4): 5324-5346.

Lizhi, T., Zhang, Y., Li, C., Zhou, Z., Nie, X., Chen, Y., Cao, H., Liu, B., Zhang, N., Said, Z., Debnath, S., Jamil, M., Ali, HM. and Sharma, S. 2022. Biological Stability of Water-Based Cutting Fluids: Progress and Application. Chinese Journal of Mechanical Engineering, 35(1): 1-24.

Nwadinobi, CP. and Okoli, JU. 2018. Development of Cutting Fluid from Spent Engine Oil. *Nigerian Journal of Technology (NIJOTECH)*, 37(4): 950 – 956.

OSHA. 1999. *Metalworking Fluids: Safety and Health Best Practices Manual*. Salt Lake City: U.S. Department of Labor, Occupational Safety and Health Administration. <https://www.osha.gov/metalworking-fluids/manual> accessed: 10th December, 2021.

Sui'l, M., Sumamaryah, E., Anggraeni, FD., Suprihana, S., Mustika, M. and Utomo, Y. 2023. Modification of Free Fatty Acid Test for Food Products Containing Fat and Organic Acid. *Journal of Food Research*, 7(6): 229-234.

Tschätsch, H. and Reichelt, A. 2009. Cutting fluids (coolants and lubricants). Chapter In: *Applied Machining Technology*. 349-352. Springer, Berlin, Heidelberg.