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Formulation of Cutting Oil Using Green Base Extract (Soya-Bean and Groundnut)

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ABSTRACT
This is an ongoing project aimed at formulating Metal Working Fluid (MWF) from green materials. The green base oil was improved by adding additives to it so as to attain the properties of commercial Metal Working Fluid (MWF). This was important because it reduces dependence on the regular cutting fluid which is mostly petroleum base, which is non-biodegradable and also has hazardous effect on machinist. All green materials used here wee Tobacco extract (antioxidants and Extreme Pressure (EP) Additives), Garlic Extract (Biocide and Extreme Pressure (EP) Additives), soya bean extract (base oil), groundnut extract (base oil), and Neem Extract (Anti corrosive agent), all oil extract went through physiochemical analysis such as Percentage yield, Refractive Index, Pour point, Flash point, PH value, Kinematic viscosity, Saponification test, Free fatty acidic, density, and Iodine value test. All values were tabulated and compared with the properties of the commercial metal Working Fluid. All parts of the analysis exhibited excellent qualities, which is an indication that the bio extract will produce a sustainable and a healthy cutting fluid.

KEYWORDS*: Extreme Pressure Additive (EP), Green Material, Commercial Metal Working Fluid (CMWF), Metal working fluid (MEF) and Base oil.*

1 INTRODUCTION

Cutting fluid known as coolant, lubricant, metal working fluid (MWF) designed specifically for metalworking processes, such as machining, stamping etc. Cutting fluids are used to reduce the negative effects of heat and friction on both tool and work piece [1]. Taylor historically reported the use of cutting fluids in metal cutting in 1894. He observed that cutting speed could be increased up to 33% without reducing tool life by applying large amounts of water in the cutting zone [2].
Cutting fluids produce three positive effects in the process of machining, and these effects are heat evacuation, lubrication on the chip–tool interface and chip removal [3]). Higher surface finish, quality and better dimensional accuracy are also obtained from cutting fluid [4]. Cutting fluids are widely used throughout industry in machining operation such as milling, grinding, boring, and turning. Estimations shows that over 320 thousand tonnes of metalworking fluids are used annually [5]. Cutting fluid may act as coolant, lubricant or both depending on the type of machining operation. During machining heat is generated and this has adverse effect on the work piece, surface finish, dimensional accuracy, tool Wear as well as production rate [6]. The need to quickly remove heat, lubricate, reduce friction during grinding, machining, cutting process among many others justifies the use of metalworking fluids. Therefore, applying metalworking fluids in a system is crucial, especially to reduce wear of the materials employed in the system. Cutting fluid used in lubrication system can be in different forms, such as solid, gas and liquid [7].

2 METHODOLOGY

Soya bean, groundnut, garlic and tobacco seed were obtained from Nigerian markets and their oil extracted from their respective seeds using the Soxhlet extractor. Determination of some specific physiochemical properties (flash point, pour point, kinematic viscosity, PH test, iodine value, free fatty acid, refractive index Density, saponification and specific gravity) were determined.

Procedure for solvent-based extraction of vegetable oil The seeds were first cleaned by removing contaminants; common contaminants often associated with the (soya-bean) seeds are sticks, strains, leaves, sands and dirt. The seeds were crushed into fine particles, powdered materials were rolled up in a filter paper and then loaded into the Soxhlet extractor, but remember the Soxhlet extractor consist of three major parts which are the condenser, the extractor, the flask. The condenser condenses the vaporized mixture of the Solvent and oil into the extractor, the extractor basically holds the grinded material rolled up in a filtered paper, the flask contains the solvent which is being heated. Hexane was the solvent used for the extra action. Hexane was filled to more than half of the flask, water was also added to the water bath container in which the flask was placed and then stirred continuous as heat was applied to enhance the leaching process. Hexane solvent has a boiling point of 69°c. The solvent was heated until its vapor

climbs through the outer tube and then enters the extraction chamber, the chamber then begins to be filled with the solvent, also the level of solvent rises in the inner tube too. When the extractor is full enough,the inner tube sends the solvent containing the extract back to the flask. The extraction process goes on till there was nothing left. After the extraction process has been concluded the extraction solvent (hexane) can be improved using distillation process [8].Care is taken to store vegetable oil extract in contaminant-free and air tight condition. The amount of extract obtained is calculated using the equation below :

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$$Oil\ Content(\%) = \frac{Weight\ of\ the\ oil}{Weight\ (g)\ of\ sample} x100$$

The entire extraction processes were carried out at Chemical Engineering Department, Federal University of Technology Minna, Niger Stare Nigeria.

Figure 1 and Figure 2 shows Soxhlet Extractor loaded with sample and Flask containing a mixture of condensed solvent and the oil

2.2 Physiochemical Analysis of Soya-bean, Groundnut, Tobacco, and Garlic Oil

(a) Determination of Kinematic Viscosity

In this work, the kinematic viscosity of the oil samples is determined using ASTM D 445 standard. The same standard has been used in the works of Didam (2016).

The determination of the kinematic viscosity of oil based on ASTM D 445 begins with determination of the velocity of flow of the oil, However the apparatus has to be prepared first to ensure the fidelity of the result. The conditions necessary for a high fidelity result stipulates; surrounding temperature of 40°c as used in [9].

The temperature of the viscometer bath was adjusted to 40oC. A calibrated thermometer was held in upright position and inserted into the bath by a holder. A clean dry calibrated viscometer was selected and carefully flushed with a dry nitrogen gas to remove the moist room air. A sample of the vegetable oil was drawn up into the working capillary of the viscometer and the timing bulb was then allowed to drain back as an additional safeguard against moisture condensing or freezing on the walls. The charged viscometer was inserted into the bath at a depth such that at no time during the measurement of the flow time was any portion of the sample in the viscometer less than 20mm below the surface of the bath as used in [10].

The viscometer together with its content was allowed to remain in the bath for 30minutes to reach the test temperature (40oC). A suction bulb was used to adjust the Head level of the vegetable oil sample to about 7mm above the first timing mark in the capillary arm of the viscometer. The vegetable oil sample is then allowed to flow freely from the first to the second marks and timing using the stop watch. The procedure was repeated to make a second measurement of flow time and the average of these determinations was used to calculate the kinematic viscosity. The procedure is repeated for the other

samples as prescribed by ASTM D 445 [9]. The equation used is shown in Table 2

(b) Determination of Density of Oil

The densities of the oils were determined using the procedure of ASTM method D-1298 The sample was brought to a specified temperature and a test portion was transferred to a hydrometer cylinder which had been brought to approximately the same temperature. The appropriate hydrometer also at a similar temperature was lowered into the test portion and allowed to settle. After which temperature equilibrium was reached. The hydrometer scale reading and temperature of test portion were taken. The observed hydrometer reading was reduced to the reference temperature by means of oil measurement table. An hydrometer correction was applied to the observed reading and the corrected hydrometer scale reading recorded to the nearest 0.1kg/m3 as density [11].

(c) Determination of Pour Point

The procedure for the determination of the Pour point followed the description contained in ASTM method (ASTM D – 97).

Oil sample was poured into the test jar to the level mark. The test jar was closed with a cork carrying high – pour thermometer. Position of the cork and thermometer were adjusted for the cork to fit tightly, the thermometer and the jar were coaxial and the thermometer bulb was immersed 3mm below the surface of the sample. After this, the test jar was placed into the cooling medium. Sample was cooled at a specified rate and examined at interval of 3oC for flow characteristics until a point was reached at which the sample showed no movement when test jar was held in a horizontal position for 5seconds. Observed reading of thermometer was recorded. 3oC was added to the recorded temperature and the result was observed as the pour point. [9]

(d) **Determination of Flash Point**

The pensky-Martens Closed Cup Test (ASTM D93) method was used to determine the flash point of oil under investigation. The test cup was filled with about 75ml of each sample of oil under investigation. It was ensured that the test flask and test sample were at least below the expected flash point of 18. The automated apparatus was started and heat was applied at a rate that temperature as indicated by temperature measuring device increased 5 oC to 6 oC. The stirring device was turn at between 100 to 110 rpm stirring downward direction. The ignition source was applied when the test sample was 23 ± 5 below the expected flash point and each time afterward at a temperature reading that was in multiple of 1. Stirring of test sample was discontinued and the ignition source was applied by operating the mechanism on the test cover which controlled the shutter so that the ignition source was lowered into the vapor space of the test cup in 0.5 and left it in lowered position for 1sec and quickly raised again to it upward position. The observed flash point reading on the temperature measuring device was recorded accordingly [12].

(e) pH Test

The pH for the test sample of the oils was measured with a pH meter. The pH meter was first calibrated with standard solution. After each reading, the electrode was cleaned with distilled water before taking another reading. This was replicated for each run. This procedure was repeated for all test samples and their pH value was read.

(f) Determination of Saponification

The saponification of the oils was determined using the procedure of ASTM method D464 This method is used to determine the total acid content, both free and combined, of all oil. (Acid number only measures the free acid). The combined acids are primarily esters formed by reaction with the neutral components present in the original oil. The saponification value is therefore a measure of all oil quality. It is determined by measuring the alkali required to saponify the combined acids and neutralize the free acids.

(g) Determination of Free Fatty Acid

Acid values of the vegetable oils were each determined by ASTM method (ASTM – D 974). 0.2 – 0.5g of sample were weighed into 250ml conical flask. 50ml of neutralized ethyl alcohol was added. The mixture was heated on a water bath to dissolve sample. The solution was titrated against 0.1M KOH using phenolphthalein as indicator.

(h) Determination of Iodine Value

The protocol for iodine value determination usually comprises a titration procedure, such as the Wijs method. In this procedure, iodine chloride was used for double-bond saturation analysis, and the content of consumed iodine was measured by titration with 0.1 mol L− 1 sodium thiosulfate solution [14].

2.3 Selection of Extreme Pressure Additives

Tobacco and Garlic were selected as additive because they are sulphur containing non-hazardous substance, though this compound is present in combined state. Sulphur is used as an extreme pressure additive in lubricant and cutting fluids [15]. The performance of MWFs was improved by adding substances that contain phosphorus, sulphur, and chlorine as EP additives [16]. Tobacco and Garlic shown good tribological properties when it was added to Neem and jatropha oil as EP additive [17]. As result shows better performance in term of tool

wear, temperature and surface finish as quantity of tobacco.

2.4 Cutting Oil Formation

Base oils are;

Groundnut oil and Soya beans oil, (petroleum base oil being replaces with the vegetable oil due to its bio degradability)

Additives

Liquid soap as an emulsifier (morning fresh), Neem as anti-corrosive agent, Tobacco seed as anti-oxidant, Garlic as biocide

pH of the base oil

The pH of Groundnut oil is between 6.59 - 6.79 (weakly acidic)

The pH of Soya beans oil is between 6.80 - 6.90 (weakly acidic)

According to [18]. Green alkaline base cutting fluid is non toxic, biodegradable and cause no harm to the environment being a sustainable product derived from renewable source. The Green alkaline base cutting fluid is cost effective, stable and with better machining properties. It promotes the healthy work environment and prevent work place injuries and illnesses compared to the ide effect of conventional mineral oil base cutting fluid.

pH of Additives

Garlic oil 6.3 (weakly acidic)

Tobacco oil 7.5 (weakly alkaline)

Neem extract 7.7 (weakly alkaline)

Emulsifier (Morning Fresh) 7.3 (weakly alkaline)

These values were all obtained using the hand-held pH meter

For typical steel/iron/cast iron, when the pH is less than about 4, protective oxide films tend to dissolve and corrosion rates increase that's is to say a low pH promoted corrosion. However, Metals typically develop a passivation layer in moderately alkaline (high pH) solutions, which lowers the corrosion rate as compared to acidic (low pH) solution.

Note that as the pH increases from 5.5 to 7.0, corrosion rate starts to decrease before gradually gaining the momentum of growth beyond pH 7.0 and reaching the maximum rate of pH 9.5. [19].

2.5 Formulation of Cutting Oil

-Base oil 100%

-Tobacco oil 5% of base oil

-Neem extract 2.5% of base oil

-Garlic oil 5% of base oil

-Emulsifier 2% of base oil.[20].

These was thoroughly agitated to ensure proper mixing, also this formulation gives good lubricity and it was in accordance with ASTM standard for cutting fluid/oil which is ASTM D7455 – 19. Standard Practice for Sample Preparation of Petroleum and Lubricant Products for Elemental Analysis.

2.6 MATERIALS

The work piece to be used was a medium carbon steel. In this study, medium carbon steel was used by virtue of its availability, properties and relatively cheap cost. Soya bean, and groundnut seed were obtained from Tunga market in Minna, also some of the additives such as neem and garlic were obtained at Gidan Mangoro, the tobacco seed was obtained from Dukku village in Gombe. The extraction and analysis of oils from the two vegetable oil seeds were carried out at Chemical Engineering Department Federal University of Technology Minna Niger State.

3 FIGURES AND TABLES

The laboratory and workshop equipment used during the physiochemical analysis include the following

Figure 1: Soxhlate extractor loaded with sample

Figure 2: Flask containing a mixture of condensed solvent and the oil

TABLE 1: Summary of Materials

S/N	Equipment (Model)	Function
1	XL400-Excel Lathe Machine	The machine tool that rotates the work piece about an axis of rotation to perform various operations
2	135-Surface Roughness Tester	Test for the surface roughness of a material
3	IR-66Infrared Thermometer	for the work piece and work tool temperature
4	Pycometer:	Laboratory device use for measuring the density or more accurately, the volume of solid.
5	Gas mask	used to protect the machining operator from inhaling toxic gases and airborne pollutant.
6	Heating mantle	laboratory device used to apply heat to containers
7	Graduated Baker	laboratory glassware used for measuring volume of liquids.
8	Electronic Weighing Balance	device for measuring weight or mass of a substance
9	Bunsen Burner	laboratory equipment that produces a gas flame which is use for heating.
10	Tri-pot Stand	three-legged frame used for supporting and maintaining the stability of other object.
11	Test sieve	used to determine the particle size of granular materials
12	Hack saw	hand tool used for cutting metals to size
13	Digital Venier Capillar	precision instrument that can be used to measure internal and external distance accurately.
14	Viscometer	an instrument used to measure the viscosity of a fluid
15	Mild steel round bar	Work piece
16	Rotary viscometer	For measuring the viscosity of the oils
17	Mortar	For crushing the seeds
18	Refractometer	For refractive index of oil

Table 2: Formulas and Descriptions

S/N	Physiochemical Analysis	Formulae	Description
1	Kinematic Viscosity	V=C×t	Where V= Kinematic Viscosity (mm2/s) C= Calibration coolant of the viscosity (mm2/s)/S
2	Free Fatty Acid or Acid Value.	A×M×56.1(f)/w	Where A=ml of 0.1m of KOH consumed by sample

			M= Molarity of KOH w=weight in grams of sample Source: ASTM D974
3	Saponification Value	SV=(A-B) ×N×56.1/w	Where A=H2SO, for blank ml B=H2SO, for sample ml w=weight of sample N=Normality H2SO4 solution 56.1= Equivalent weight of Potassium Hydroxide Source: ASTM D464
4	Specific Gravity	SG=Do/DA	Where Do=Density of oil DA=Density of Air

3. RESULTS AND DISCUSSIONS

Table 3: Comparison of the Physiochemical Analysis of Extract with the Commercial Metal Working Fluid (CNC COOLANT)

Physiochemical Analysis	**Tobacco Oil/Extract**	**Soyabean Oil/Extract**	**Groundnut Oil/Extract**	**Garlic Oil/ Extract**	**Commercial Metal Working Fluid (CNC Coolant)**
Iodine Value gl2 /100g of Oil	130.2	73	38.6	100	28
Density g/ml at 25°C	0.923	0.917	0.926	1.083	0.932
Specific Gravity	1.79	0.917	0.901	0.894	0.932
(gram/mole)					
Flash Point °C	220	303	315	47	175
Free Fatty Acid or Acid Value (mg KOH/g oil)	15.05	0.60	4.00	12.69	16.92
pH	6.5-7.2	6.8-6.9	6.6-6.8	6.3-6.7	8.5
Kinematic Viscosity (mm2/s)	38.21	35.00	38.00	32.1	29
Pour Point °C	-5	-20	-23	-7	-22
Refractive Index at (40°C)	1.452	1.459	1.463	1.471	1.482
Saponification Value (mg KOH/g oil)	102.5	187	184	166	142.5

Oils with iodine values higher than 115g are considered to be drying oil and also highly unsaturated in nature, this high saturation also makes it oxidative [21]. Comparing the gotten values of the base oil and addictive, it could be seen that all oil are saturated and also falls within range. This further shows that all extract has a good quality as compared with the commercial metal working fluid

Comparing the densities of the base oil with the control, it could be seen that the base oil (soya bean and ground nut oil) are fairly in the same range as the control with a value of +or – 0.006.

The specific gravity is used alternatively with the density valve., it could be seen that the base oil falls within same rage too with a value of +or- 0.02.

The flash points of these extracts are the lowest temperature at which its vapor ignites if given an ignition source, however comparing these temperatures gotten with the control, it therefore showed that the flash point for both base oils are higher when compared with the control which makes using these set of base oil safer. But the high value of the garlic extract will have no effect with the cutting oil formulation because it is an addictive and would be added in a very low quantity therefore it will pose no hazard during Machining operation, the area of flash point concern is only on the base oil

The more the content of fatty acid in any fluid or oils the more oxidation and rancidity it will experience, therefore affecting the shell life of such fluid or oil [22] [23]. From the values of free fatty acids gotten from the table, it was observed that all values fell below the control value which then means that all extracts will have less oxidation, better shell life and also act resistance to rancidity as compared with the commercial cutting oil.

Most cutting fluids have a pH of 8.5 -9.6, but there are also products that have a lower pH during use due to contamination [24]. Although the base oil here showed weakly acidic values tending towards complete alkalinity which can be manageable, considering that all other analyses carried out showed excellent values on the use of the base oil.

Viscosity has considerable influence on the properties of a cutting fluid. Higher viscosity improves the lubrication abilities of the fluid, but decreases the cooling performance. Lower viscosity provides better cooling performance and easier removal of solid particles. On the other hand, this may lead to a lack of lubrication between tool edge and work piece, especially at higher production speed. Poor surface quality and increased tool wear can occur. So, viscosity affects the speed, at which the liquid fills the contact zone between cutting tool and work piece, and the thickness of the liquid film. Viscosity measurement helps to find a balance between fastest possible machine parameters and best possible surface quality of the work piece.[25] lubricants range from 5 to 50, the lower the number, the more readily the oil flows.[26] Comparing the gotten values of the base oil with these standards, it can be seen that all extracts are within range and suitable for use.

The pour point is the lowest temperature at which the oil will pour or flow when it is cooled, without stirring, under standard cooling conditions. Pour point represents the lowest temperature at which oil is capable of flowing under gravity. Major attention and comparison here would be the base oil against the control fluid which was observed to be in the same range of +1or -1, which make the base oil suitable for use.

The higher the refractive index, the closer to the normal direction the light will travel. When passing into a medium with lower refractive index, the light will instead be refracted away from the normal, towards the surface. Furthermore, the more or higher the refractive index the more room it gives for the growth of microbial organisms [27]. The corresponding values of extracts compared with the control are all in the same range which is also another reason these green materials can be used.

The higher the saponification value, the lower the fatty acids, the lighter the mean molecular weight of triglycerides and vice-versa. [28][29]. Practically, oils with high saponification values are more preferable when it comes to cutting fluid, because the more the content of fatty acid in any fluid or oils the more oxidation and rancidity it will experience, thereby affecting the shell life of such fluid or oil [22] [23]. Comparing values gotten it could be seen that all extracts have higher saponification values when compared with the control which makes it veritable for use.

4. CONCLUSION

All physiochemical analysis carried out in this study showed an excellent characteristic when compared with the CNC coolant, except for the pH value of the base oil which fell into the weakly acidic range but was compensated by other analysis carried out, therefore making it suitable for the formulation of a Green Metal working Fluid

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"Eco-Friendly, Non-toxic Fluid for Sustainable Manufacturing and Machine Processes"

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