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Lubricity Assessment of Neem and Castor Oils and their Blends in Machining Mild Steel

Kazeem Babalola Olawale[a*], Isuwa Suleiman Aji[b], Robinson I. Ejilah[c]

[a,c]*Department of Mechanical and Production Engineering, Faculty of Engineering, Abubakar Tafawa Balewa University Bauchi – Nigeria*

[a]*School of Technical Education (Secondary), Federal College of Education (Technical) Bichi Kano - Nigeria*

[b]*Department of Mechanical Engineering, Faculty of Engineering, University of Maiduguri - Nigeria*

[a]*Email: olawalebabs42@yahoo.com*

[b]*Email: suleimanaji@yahoo.com*

[c]*Email: rejilah@gmail.com*

Abstract

Mineral oil and sulfonates have been the basic source of cutting fluid formulations, but their uses have been questioned nowadays as regards to cost, health and environmental issues. The use of vegetable based cutting fluids is increasing and minerals based cutting fluids are likely to be replaced with vegetable based cutting fluids. The present study assessed the lubricity of blended oil from Castor and Neem seeds. These oils were extracted by mechanical method. The blends were formulated by varying the amount of each oil in the blend to see its effect in the properties and characteristics of the oil. The oil obtained was investigated for physicochemical parameters and fatty acid profiles. The fatty acid in Neem oil showed the presence of oleic acid (41.9%), linoleoic acid (19.50%), stearic acid (18.68%), palmitic acid (15.56%) linolenic acid among others, while that of Castor oil had palmitic (0.46%), Stearic (0.72%), Linoleic (4.4%), Linolenic (0.2%), Dihydroxylstearic acid (0.69%) and ricinoleic acid (90.58%). Lubricity of the formulated cutting fluid was tested using four balls tribo meter tester and the results obtained showed minimum Wear Scar Diameter of 0.13 mm which is the least among the formulated oils obtained in the 60% Neem and 40% Castor oil; this implies that this formulation has maximum lubricity in terms of friction reduction as compared to other formulated oil and the conventional soluble oil available in the market. This combination was found to be the optimum sample compared to other blends.

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* Corresponding author.

The formulated cutting fluids were further tested in machining mild steel. The chip thickness formed using the formulated cutting fluid at 90rpm was found to be 0.203 mm which is higher than that of the conventional cutting fluid obtained as 0.17 mm at constant depth of 2 mm; the high chip thickness value is due to its better lubricity property which allows for better metal removal rate, good surface finish and continuous chip formation.

Key words: Lubricity; vegetable oil; Castor oil; Neem oil ; mineral oil; cutting fluids and formulated oils.

1. Introduction

Machining can be used to create a variety of features including holes, slots, pocket, flat surfaces and even complex surface contours [1].While machined parts are typically metals, almost all materials can be machined, including metal, plastics, composites and wood. According to [2], 98% of the energy in machining is converted to heat which cause very high temperature at tool-chip zone while the remaining energy (2%) is retained as elastic energy at chip. Tool failure, poor surface finish and seizure between tool and chip occur during metal cutting [3].

The reasons for this had been traced to heat generated during cutting as tools are forced through the excess of materials of the work pieces which normally take place ahead of the cutting area. Therefore, to minimize energy lost, generate good surface finish and protect the life of cutting tool, the use of appropriate cutting fluid is inevitable .Lubrication has been shown to enhance tool life by reducing metal-metal contact, reducing friction at the contact surface thereby preventing welding of the metal parts and subsequent early tool damage [5]. Bello (2011) describes cutting fluid as a material that make surface smooth and slippery and they are used to reduce heat, friction, wear and vibration during machining operations. Cutting fluid can improve the efficiency of machining operations by reducing the friction between the cutting and non-cutting surfaces of the tool; it aids in flushing out the chips from the work area, and cools the cutting tool and the work piece and prevents rusting of newly machined surface. It also brings out improved surface finish. Approximately ten thousand machine operators in the world developed cancer, asthma and other related diseases and out of which nine thousand died annually [6]. The cause has been linked to physical contact and exposure of machine operators to the petro-chemical based cutting fluids used in machining operations [7].Mineral oil and sulfonates have been the basic source of cutting fluid formulations [8,9]. Petroleum based soluble oil contains additives such as chlorine and sulfur used to improve the physico-chemical properties and performance of cutting fluids [10,11] however, these chemicals can be very harmful to human beings and the environment. Soluble oil generally suffers from many disadvantages, such as, high toxicity to the environment, poor biodegradability and costly. Synthetic lubricants are designed for use in extreme conditions of temperature, pressure, radiation and have excellent lubricity and thermal stability. Unfortunately, they are relatively costly and have poor biodegradability, therefore showing similar disadvantages like soluble oil [12].

It is no surprise therefore that interest in vegetable oil-based cutting fluid is growing compared with mineral oil; vegetable oil may enhance the cutting performance, extend tool life and improve the surface finishing according to industrial study [13]. They have many environmental benefits which include susceptible to degradation by oxidation or hydrolytic reaction. Vegetable oils are by their chemical structure, long chain fatty acids tri-esters of glycerol and are capable of providing the desired lubricant properties, such as good boundary lubrication, high viscosity index, high flash point and low volatility [14]. These oils are extracted from plants by placing the relevant part of plant (seeds, leaf, root etc.) under pressure to squeeze the oil out. Recent studies have shown that non-edible vegetable oils like Neem, Castor, Mahua,Rice bran are safe and convenient for use in a wide variety of manufacturing applications [15].

1.1 Scope of the study

The work will cover the following area:

i. Extraction of Castor and Neem seeds oil by mechanical pressing method.

ii Utilization of blended Castor and Neem seed oil in machining mild steel.

1.2 Vegetable oil plants

Castor plant (*Ricinus Communis*), from which Castor beans and oil are derived are native to West Africa, is now grown in most part of Nigeria.

It is becoming an abundant seed crops in the North and Southwestern part of the country [16, 17]. It grows naturally over a wide range of geographical regions and may be activated under a variety of physical and climatic regions.

The Castor-plant is easy to grow and is resistant to drought, which makes it an ideal crop for the extensive semi-arid regions globally. Castor beans could become a farming alternative to provide income for over one hundred million unemployed youths in Nigeria [18].

Salunke and Desai (1998), reported that Castor beans contain about 30-35% oil which can be extracted by variety of process, such as, mechanical extraction and solvent extraction.

Furthermore, Kularm and Sawant (2003) also reported that Castor beans contain 35-55% oil by weight for high yield breed types and has one of the highest viscosities among vegetable oils, with a molecular weight of 298g.

Neem (*Azadirachtaindica*) is one of the most versatile multipurpose trees with immense potentials found in the tropics; it has high useful non wood products which include leaves, bark, fruits, oil, and gum.

The Neem tree is predominantly found in the northern part of the country in Nigeria in commercial quantity, which makes it easily accessible for this research. It is an evergreen tree that is well adapted to all weather conditions with the ability to re-sprout after cutting and to re-grow it canopy after pollarding (Obi, 2000). Unfortunately, this plant has been scarcely utilized, serving only as a source of waste and a disturbance to the environment. Table 1 show some interesting combinations present in the Castor and Neem seed oils

Table 1: properties of Castor and neem seed oil combined

Properties name	Castor oil	Neem oil
Ricinoleic acid	90.2%	-
Oleic acid	2.8%	56.98%
Stearic acid	0.9%	21.11%
Density	0.956-0.963g/ml	0.889

This work made effort to assess their potentials both as a single oil and as blends of the two oils solely in machining operations. The high value of Ricinoleic acid in Castor oil and high Oleic acid in Neem oil when blended could provide great potential through provision of good surface finish, continuous chip formation and extend the tools life.

2. Materials and Method

Castor and Neem seeds oil were obtained from Bichi local government area of Kano State in Nigeria. Commercial grade Mild steel was used for the experiment. The equipment utilized in the study are presented in Table 2.

Table 2: Equipment and the parameters measured

Equipment	Parameters measured
Lathe machine (model XL400)	Machining operation
HSS cutting tool (19mmx 19mm)	Turning
Digital venier caliper	Measuring tool
Conical flask	Measuring tool
PH Meter (Jenway3510)	PH
Viscometer(model TT-J)	Viscosity
Optical Electron Spectrometer (MS6500K)	Chemical composition
Mechanical Extractor	Oil Extraction
Micrometer screw gauge	Measuring tool
Thermocouple	Temperature
Pensky-martens flash tester	Flash point tester
Four ball tester (TR-30HLE-PHM- 200)	Friction and wear tester.

3. Methodology

3.1 Extraction of Castor seeds oil

The Castor seeds (Plate 1) for this research were obtained from Bichi Local Government Area of Kano state

Nigeria, in view of its abundance in the area. The seeds were prepared by removing the endocarp, oven dried at the temperature of 105^0C to reduce the moisture content. Grinding machine was used to crush the beans into a paste (cake) in order to weaken or rupture the cell walls and then pressed mechanically in a drum to release the oil. The Castor oil obtained has a distinct odor, viscous, pale yellow, nonvolatile and nondrying oil. It was filtered to remove the various unwanted particles left in the extracted oil.

3.2 Extraction of Neem seed oil

The Neem seeds (Plate 2) used for this work were also obtained in Bichi local Government in view of its abundant in the area. The fruits were collected in a drum, and the kernels separated to obtain the seeds. Later, the seeds were oven dried at temperature of 105^0C and then fed into the oil extracting machine using mechanical pressing method with the oil collected in a drum. Filtration of the oil was done to remove the various unwanted particles left in the extracted oil.

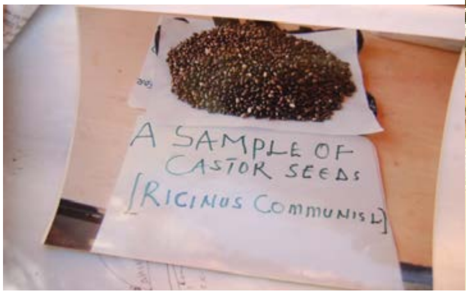

Plate 1: Castor Seed

Plate 2: Neem Seed

3.3 Formulation of the cutting fluids

The formulation of the cutting fluid was conducted in a 250ml seven necked round bottom flask connected to an overhead motor stirrer, a thermometer and an open separating funnel. Castor oil in various proportions was blended with Neem oil. The formulated oils in their various proportions were charged into the round bottom flask. The mixture was allowed to stir for 30 minutes at 40^0C. The blending ratios of formulated cutting fluids are presented in Table 3.

Table 3: Blending proportions of the formulated Cutting fluids

% Oil sample	Oil quantity ml	Blend ratio	Additives	% Formulation	Remark
100Neem	250	100:1	-	100Neem oil	Cutting fluid
100Castor	250	100;1	-	100Castor oil	Cutting fluid
90Neem+10castor	250	90:10	-	90Neem+10castor	Cutting fluid
80Neem+20castor	250	80:20	-	80Neem+20castor	Cutting fluid
70Neem+30Castor	250	70: 30	-	70Neem+30Castor	Cutting fluid
60Neem+40Castor	250	60: 40	-	60Neem+40Castor	Cutting fluid
50Neem+50Castor	250	50: 50	-	50Neem+50Castor	Cutting fluid

Plate 3: Formulated cutting fluids

4. Results and Discussions

4.1 Determination of fatty acids profile of Castor and Neem seed oil

Table 4 presents the fatty acid profile of the two seed oil used for this experiment, while in table 4, the physico-chemical properties of the oils are presented as determined from experiment.

Table 4: Fatty acid profile of Castor and Neem seed oil

Fatty acid	%composition (Neem oil)	%composition (Castor)
Oleic acid (C18:1)	42.20	2.8
Linoleic acid (C18:2)	19.50	4.4
Linolenic acid (C18:3)	0.09	0.2
Erucic acid (C22:1)	0.28	-
Palmitoleic acid (C16:1)	1.88	-
Palmitic acid (C16:1)	15.55	0.69
Stearic acid (C18:0)	18.32	0.72
Arachidic acid (C20:0)	0.18	-
Behenic acid(C22:0)	0.11	-
Lignoceric acid(C24:0)	0.71	-
Dihydroxy stearic acid	-	0.43
Ricinoleic acid(C18:1)	-	90.58
Total	100	99.82

From the results of fatty acid shown in Table 4, only unsaturated fatty acids such as oleic acid, linoleic acid and linolenic acids imparts the most on the quality of seed oil based lubricating oils. The oleic acid content suggests the degree of oiliness of seed oil samples (Georing, 1992). Therefore, it could be seen that oleic acid content of Neem oil is higher than that of Castor oil and therefore, when blending the oil together it would chemically provide better boundary lubrication for two contacting metallic surfaces. It could also be seen from the table that the linolenic acid content of Castor oil is higher. According to Ahmed and Young (1982) and Asiedu, (1989), a correlation exists between linolenic acid content and the stability of seed oil. The stability is highest for the oils containing the smallest amount of linoleic acid; hence, this explains why 100% Castor oil is more stable than other formulated oils.

Table 5: Determination of physico-chemical properties of Neem and Castor oil

Oil sample (%)	Density at 26.3 °C ASTM D97	Refractive index ASTM D97	Saponifiion no. ASTM D 93	Iodine value ASTM D482	Specific gravity ASTM D93	Viscosity at 23.6°C ASTM 189	Flash point °C ASTM D92	Pour point °C ASTM D97	Emulsion stability	Acid value Mg KOH/g ASTM D95	Viscosity index
100 neeem	4.83	1.466	194.69	88.83	0.917	12.00	329	-38	Good	8.415	50
100 Castor	0.945	1.465	179.23	83.50	0.961	65.33	368	-39	Excellent	17.952	53
90neem+ 10 Castor	0.934	1.467	39.55	86.29	0.961	21.33	367	-37	Excellent	15.708	56
80neem+ 20 Castor	0.923	1.468	9.817	30.46	0.927	10.00	368	-37.5	Excellent	7.854	55
70neem+ 30 Castor	0.892	1.468	5.049	63.45	0.929	20.67	370	-35.1	Excellent	21.879	54.5
60neem+ 40 Castor	0.835	1.469	39.83	81.23	0.933	27.33	375	-33	Excellent	24.123	56
50neem+ 50 Castor	0.795	1.470	31.416	116.75	0.937	25.33	354	-42	Excellent	22.40	50

Table 6: Lubricity test

Sample	Co-efficient of friction	Wear (mm)
100% Neem	0.25	0.29
100% Castor	0.20	0.16
90% Neem and 10% Castor	0.21	0.17
80% Neem and 20% Castor	0.26	0.23
70% Neem and 30% Castor	0.19	0.18
60% Neem and 40% Castor	0.14	0.13
50% Neem and 50% Castor	0.17	0.15
Soluble oils	0.32	0.38

Table 7 presents the experimental results of machining operation conducted with formulated oils using mild steel as work piece. The values of chips thickness, chip compression, coefficient of friction and chips formation obtained from turning mild steel at various speeds, depth of cut, feeds rate and angle of cut using blends of Neem and Castor seed oil at varying blend percentages were presented. Chip thickness was obtained directly by measuring with a micrometer screw gauge, while chip compression and coefficient of friction were evaluated and recorded. It can be seen that the formulated cutting fluids showed relatively high chip thickness of 1.68 mm than the conventional cutting fluid of 1.43 mm at the cutting speed of 250 rpm, feed and depth of cut as 0.5 mm/rev and 2 mm respectively. At low speed, the formulated cutting fluid recorded chip thickness values of 1.47 mm while that of conventional cutting fluid has 1.36 mm. This high chip thickness value is associated with low coefficient of friction. Low coefficient of friction is an indication of a good lubricating oil. Similar result was reported by Obi and his colleagues (2009). Increase in coefficient of friction will cause an increase in thermal force and mechanical variables during machining. Hence, the higher the coefficient of friction, the higher the cutting force and thermos-mechanical properties will be observed. The chip formation tends to change from continuous to discontinuous, but as percentage of Neem oil in the blend is increased, lower temperature build-up is observed which improved the flow of chip formation better than obtained when individual oil is used. It is observed that formation of chips was continuous throughout; this implies that local temperature has decreased and the coefficient of friction is decreasing. This is attributed to better cooling and lubrication of the cutting surface.

Table 7: Characterization of machining operation

% Oil sample	Depth of cut (mm)	Feed (mm/rev.)	Chipthickness (mm)	Chip compression	Coefficient of friction	Chip formation
100 Soluble oil (S	1.00	0.24	1.04	1.09	0.29	Continuous
	2.00	0.29	1.15	1.35	0.32	Continuous
	3.00	0.32	1.25	1.45	0.34	Continuous
	4.00	0.43	1.36	1.34	0.37	Continuous
	4.50	0.51	1.33	1.23	0.14	Continuous
100 neem oil (N)	1.00	0.24	1.52	1.56	0.23	Continuous
	2.00	0.29	1.42	1.63	0.22	Continuous
	3.00	0.32	1.21	1.67	0.24	Continuous
	4.00	0.43	1.41	1.58	0.26	Continuous
	4.50	0.51	1.44	1.67	0.28	Continuous
100 Castor oil (C)	1.00	0.24	1.43	1.66	0.16	Continuous
	2.00	0.29	1.54	1.57	0.25	Continuous
	3.00	0.32	1.47	1.60	0.22	Continuous
	4.00	0.43	1.50	1.93	0.21	Continuous
	4.50	0.51	1.54	1.68	0.21	Continuous
90N+10C	1.00	0.24	1.45	1.88	0.18	Continuous
	2.00	0.29	1.46	1.59	0.21	Continuous
	3.00	0.32	1.48	1.73	0.23	Continuous
	4.00	0.43	1.53	1.88	0.25	Continuous
	4.50	0.51	1.45	1.97	0.28	Continuous
80N+20C	1.00	0.24	1.45	2.03	0.22	Continuous
	2.00	0.29	1.50	1.96	0.27	Continuous
	3.00	0.32	1.50	2.28	0.22	Continuous
	4.00	0.43	1.63	1.96	0.25	Continuous
	4.50	0.51	1.53	1.99	0.15	Continuous
70N+30C	1.00	0.24	1.03	1.82	0.18	Continuous
	2.00	0.29	1.30	2.25	0.27	Continuous
	3.00	0.32	1.27	1.83	0.17	Continuous
	4.00	0.43	1.66	1.66	0.18	Continuous
	4.50	0.51	1.35	1.80	0.21	Continuous
60N+40C	1.00	0.24	1.64	1.78	0.15	Continuous
	2.00	0.29	1.70	2.27	0.16	Continuous
	3.00	0.32	1.57	1.97	0.13	Continuous
	4.00	0.43	1.53	2.43	0.17	Continuous
	4.50	0.51	1.67	1.92	0.14	Continuous
50N+50C	1.00	0.24	1.20	2.07	0.24	Continuous
	2.00	0.29	1.43	1.93	0.21	Continuous
	3.00	0.32	1.45	2.09	0.17	Continuous
	4.00	0.43	1..66	2.25	0.23	Continuous
	4.50	0.51	1.39	1.76	0.31	Continuous

4.2 Boundary Wear Reduction Properties

The saponification, ester and the saturated fatty (oleic) acid profiles **(**Table 3) provides evidence that more soap and ester are likely to be produced from the blend of Neem and Castor oil. It is also known that seed oils with higher saponification or ester values provide better boundary lubrication (Ejilah, 2009).The soapy film produced by such oil during boundary lubrication reduces wear significantly. This further collaborated the results of wear reduction behavior of blended seed oils (Table 5). However, the notable wear behavior of seed oils is somewhat in order of their saponification values (Table 4) and hence provides an overriding economic advantage over mineral oil- based lubricant. The compositions of oleic acid in seed oil suggest its degree of oiliness, which is an important property in boundary lubrication conditions. Oiliness in this context refers to the ability of oils to adhere to metal surfaces which depends on polarity of the molecules (Goering, 1992). Hence,it could be inferred that 60N+40C oil tend to exhibit a higher degree of oiliness than other formulated oils, and therefore expected to perform better in lubricating metal surfaces than other blend ratios and therefore seen as the optimum blend.

5. Conclusion

It has been established that environmentally-friendly vegetable-based oil could successfully replace petroleum-based mineral oils as cutting fluids with modifications through blending of the oilswhich can provide better performancein cutting operations. The work has therefore shown that: (i) The optimum sample of blended oil falls within the range of 60%Neem and 40% Castor oil which satisfies all the requirements of a standard cutting fluid. Chip thickness formed using formulated cutting fluid was found to be 0.203mm which is higher than that of the conventional cutting fluid under similar operating conditions.The high chip thickness value is due to better lubricating properties of the formulated cutting fluid, and this allows for easier and deeper penetration of cutting tool into work piece and better metal removal rate; an advantage of quick production process. The chip compression values obtained for all the blends ratio and individual oil showed no significant difference in the chip compression and chip formation was continuous throughout the experiments.

6. Recommendation

Further research work on assessment of the formulated cutting fluids may be to optimize the process parameter in turning alloys under different machining conditions using Taguchi and ANOVA techniques to investigate optimum parameters for alloys.

Investigation on how to enhance the shelf life of vegetable oils to prevent rancidity and susceptibility to auto-oxidation or hydrolytic reaction for higher shelf life and improved performance

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