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Characterization of Balanites Seed Oil as a Metal Cutting Fluid

Isah Hussaini Wara[1,2], Abdu Salihi[1]
[1]*Department of Mechanical Engineering, Bayero University Kano, Nigeria*
[2]*Industrial Training Fund, Nigeria*

Abstract: The use of oils derived from plants in non-food industries such as lubricants, pharmaceuticals, and cosmetics has received widespread interest due to its non-toxic, biodegradable, and ecologically beneficial properties. This paper presents the formulation, characterization and performance evaluation of the developed cutting fluid from Balanites (Aduwa) seed oils (turning operation at varying cutting speeds of 278rpm and 370rpm with 1mm and 1.5mm, a depth of cut, and a constant feed rate of 0.5rv/min). The formulation of the cutting fluid was done by mixing the balanites oil with emulsifiers and additives. Three emulsion samples, BCF-10 (10% balanites oil concentration), BCF-20 (20% balanites oil concentration), and BCF-30 (30% balanites oil concentration), as well as a control sample, CCF, were prepared. The results showed that sample BCF-30 had better physicochemical properties in terms of viscosity, flash point, and pH value with 29.3 cP, 285 ^{o}C, and 9.20 respectively compared to the control sample CCF with 25.4 cP, 250 ^{o}C, and 8.03 respectively, while sample BCF-10 had the highest density with 0.96 g/ml compared to sample CCF with 0.92.

Keywords: Balanites oil, Balanites seed, cutting fluid, flash point, viscosity, pH value

I. Introduction

Metal cutting fluid chemistry moved from simple oils to complex water-based technologies, and the evolution of these products was initially designed to increase the cooling qualities and fire resistance of straight oils [1]. Smoke and fire were considerably decreased in factories by emulsifying the oil in water, thus improving working conditions [2]. The presence of water in the cutting fluid increased tool life by minimizing wear since the fluid kept the tools cool [3]. Metal cutting fluids are used in the metal cutting industry as both a coolant and a lubricant [4]. The use of the right type and form of cutting fluid has a significant impact on the production economics of metal cutting operations [5].

Vegetable-based oils have long been recognized as environmentally safe lubricant base stocks [6], with some appealing lubricating qualities in addition to their non-toxic composition [7]. Unlike mineral and synthetic base stocks, vegetable oils are a renewable resource that may be generated locally and represent the future alternative to fossil carbon-based substrates [8]. Furthermore, they can be used without any further processing, making them cost-competitive with mineral and synthetic base stocks [9]. The primary advantage of these base stocks over highly contaminant mineral and synthetic base stocks is that they are completely biodegradable [10].

Machining speeds can be substantially enhanced if the cutting surface is kept cold and greased. Water was the initial cutting fluid, but recent innovations have resulted in the introduction of improved water-oil emulsions or soluble oils containing specific compounds, which significantly improve its lubricating, high cooling power, rust preventing, and detergency capabilities. Soluble oils are appropriate for common machining processes where cooling, lubrication, cleaning, and severe pressure characteristics are required [11]. Globally, around 125 million metric tons of vegetable oils are produced each year. Vegetable oils are advantageous as lubricant base stocks because of their outstanding lubricity, attractive viscosity-temperature properties, high flash points, and compatibility with mineral oil and additive compounds [12]. Their broad application in lubricant formulation is limited because to weak thermal/oxidative stability and poor low-temperature fluidity. When combined with existing additives (antioxidants, pour point depressants) and diluents or functional fluids, genetic and chemical modification of vegetable oils can overcome these disadvantages [13].

Vegetable oils are the oils made from plants such as palm, soyabean, sunflower, rapeseed, pongamia pinnata and coconut, etc. [14][15]. The plants are locally obtainable and can produce oil for various purposes ranging from oil for food and skin care products to industrial applications such as lubricant and cutting fluids [16].

Balanites (*Aduwa*) plant is a drought-tolerant perennial tropical ever green tree which belongs to family of *Balanitaceae*, commonly found in the Northern part of Nigeria. The tree grows from 4.5 – 9 meters in height [17]. The plant has a multiplicity of uses and almost every part of the plant is useful including the leaves, fruits, thorns bark and roots. The kernel of *Balanites* (*Aduwa*) yields oil which is used as ointment and balms containing many drugs or dressing wounds, it is also shown to have anathematic activity [18]. Fig 1 shows the Balanites seed

Figure 1: Balanites Aegyptiaca Plant, Fruit and Kernel

Cutting Fluids

A cutting fluid is a type of coolant and lubricant designed specifically for metalworking and machining processes. There are various kinds of cutting fluids, which include oils, oil-water emulsions, pastes, gels, aerosols (mists), and air or other gases. They may be made from petroleum distillates, animal fats, plant oils, water and air, or other raw ingredients. Depending on the context or on the type of cutting fluid being considered, and it may be referred to as a cutting fluid, cutting oil, cutting compound, coolant, or lubricant [19]. Cutting fluids are used in metal machining for a variety of reasons such as improving tool life, reducing work piece thermal deformation, improving surface finish and flushing away chips from the cutting zone. The need for a cutting fluid depends on the severity of the particular machining operation, which may be defined as the level of temperatures and forces encountered, the tendency for built-up edge (BUE) formation, the ease with which chips produced can be removed from the cutting zone, and how effectively the fluids can be applied to the proper region at the tool-chip interface. The relative severities of specific machining processes in increasing order of severity are: sawing, turning, milling, drilling, gear cutting, thread cutting, tapping, and internal broaching [20].

This paper characterization the viability of *Balanites* (*Aduwa*) seed oil as raw material for the production of metal cutting fluids (Coolant) as a potential substitute to conventional cutting fluids and lubricants

II. Cutting Fluid Properties

Cutting fluids were initially considered as simple oil that is applied with brushes to lubricate and cool the machine tool. As cutting operations became more severe, the formulations of cutting fluids became more complex [21]. In addition to providing a good machining environment, a cutting fluid should also function safely and effectively during machining operations. A good cutting fluid should have the following properties Corrosion Protection, Stability/Rancidity Control, Transparency and Viscosity, Health and Safety Considerations, Toxicity, Flammability and Misting [22].

Functions of Cutting Fluids

The main functions of cutting fluids are:

i. Cooling

Metal cutting operations generate heat due to tool friction and energy used in deforming the material [23]. Reducing cutting-tool temperature is important since a small reduction in temperature will greatly extend cutting tool life. As cutting fluid is applied during machining operations, it removes heat by carrying it away from the cutting tool/workpiece interface. This cooling effect prevents tools from exceeding their critical temperature range beyond which the tool softens and wears rapidly. The cooling effect is achieved through a variety of heat exchange processes, such as conduction, convection, evaporation (or vaporization), and very little radiation.

ii. Lubrication

Besides cooling, cutting fluids also aid the cutting process by lubricating the interface between the tool's cutting edge and the chip [24]. By preventing friction at this interface, some of the heat generation is prevented. This lubrication also helps prevent the chip from being welded onto the tool, which interferes with subsequent cutting. Lubrication effect of the cutting fluid occurs mainly in these two regions, and it is believed that liquid films cannot be sustained along these interfaces in most cutting operations especially in high-speed machining [24].

iii. Chip removal from the cutting zone

Cutting fluids also assist in flushing away the chips and metal fines left in the work-piece interface to prevent the occurrence of built-up edge (BUE) and clogging of tool. The cutting fluid ability of sweeping the chips away from the cutting zone depends on its viscosity and its volume flow, besides, of course, the kind of machining operation and chip type formed [24]. In some machining operations such as drilling and sawing, this function is very important, because it may avoid chip obstruction and, consequently, tool breakage. Cutting Fluids can be used for manual application, flood application, jet application and mist application [24]

Cutting parameters

In turning, the speed and motion of the cutting tool is specified through several parameters. The important task in turning operation is to select cutting parameters for achieving high cutting performance. Three cutting parameters namely cutting speed, feed rate and depth of cut need to be resolved in a turning operation [25].

Cutting Speed

The term cutting speed of a tool is the speed at which the material is removed by the tool from work piece. In a lathe work it is like peripheral speed of the work piece in m/min [26]. Cutting speed is also the relative speed at which the tool passes through the work material and removes metal. It is normally expressed in meters per minute (or feet per inch in British units). It has to do with the speed of rotation of the workpiece or the tool, as the case may be. The higher the cutting speed, the better the productivity. For every work material and tool material component, there is always an ideal cutting speed available, and the tool manufacturers generally give the guidelines for it. Mathematically is given as [27].

$$Vc = \frac{\pi DN}{1000}\left(\frac{m}{min}\right) \qquad (1)$$

where, $D$and N are diameter (mm) and cutting speed (rpm)of work piece respectively.

Feed (f)

The feed of the cutting tool in lathe operation is the linear distance, the tool advances for each revolution of the work piece in mm [28]. The speed of the cutting tool's movement relative to the work-piece as the tool makes a cut. The feed rate is measured in inches per minute (IPM) and is the product of the cutting feed (IPR) and the spindle speed (RPM) [29].

Depth of cut (d)

The term depth of cut is the measured perpendicular distance from finished machine surface to the rough surface of the work piece on mm. Cutting speed and feed rate come together with depth of cut to determine the material removal rate, which is the volume of work-piece material or metal that can be removed per time unit [30].

Chip Formation

Chips are produced by shearing, according to microscopic examination of chips obtained in actual machining operations. Shearing takes place along a shear zone (usually a long defined plane referred to as the shear plane) at an angle, called the shear angle [31].

Chip Thickness

Chip thickness ratio is given by [32],

$$r = \frac{t_C}{t_O} \qquad (2)$$

Where t_C= chip thickness before cutting and t_O= chip thickness after cutting.

The value of chip thickness ratio is always less than 1. If the ratio r is larger i.e. close to 1, the cutting action is good defined by good surface finish. The ratio is affected by process parameters [33].

III. Experimental Design

For this work the dependent variables used are Temperature rise, Surface finish, Force and Energy dissipated during cutting, and surface integrity of the work piece. The independent variables are: Cutting speed, feed and depth of cut and cutting fluids. Taguchi method was used in the design of the experiment; specifically L9 with three levels was used with three replications. [34].

The method involves Extraction of Balanites seed oil, characterization, formulation of the cutting fluid and preparation of the emulsion.

Extraction of Oil from Balanites (*Aduwa*) Seed

The Balanites (Aduwa) seed used for this work was obtained from Janguza market, outskirts of Kano Metropolis. The samples were washed to remove the fruits covering the kernel and then sundried. The shells of the kernel were cracked manually using a metal hammer to obtain the seed. Two (2kg) kilograms of the kernel seeds was obtained from 9kg of the fruits collected. Mechanical method of oil extraction was used for the purpose of this work.

The Mechanical extraction commenced after the ground sample of the balanites seed were formed into cake and then preheated in an oven in order to weaken the cell walls to release fat for the extraction. The steamed cake was then cold pressed manually on a manual oil expelling machine as shown in Fig. 2. The opening on the base of expelling machine allowed the oil to be drained and collected into a container.

Figure 2: Manual Cold Pressing Machine Setup

However, for extraction of oil for large quantity of samples that weighed 10kg and above, an automatic screw press oil expelling machine, which has a continuous mechanical screw press for extraction is used. After the kernel shells were cracked and the seeds were sundried, the extraction process commences by putting the collected seeds inside the feed hopper. The movement of the helical screw forced the oilseed mesh through the barrel by the action of the revolving worms. This conveys, grinds and presses the seeds inside the cylinder barrel with the aid of the worm shaft until oil is squeezed out of the seed. The oil extracted is drained through the oil barrel into the oil container where it is collected, while the residual cake is discharged in to a container at the cake outlet where it is collected. This system is being powered with electric motor, the mechanical pressing system is shown in Fig. 3.

Figure 3: Continuous Mechanical Screw Pressing Machine

Formulation of Cutting Fluids from Balanites Seed Oil

Balanites oil based concentrate was formulated by mixing the oil with Sodium Lauryl Sulfate, Sulphur and Phenol in the ratio of 80:10:5:5 respectively as shown in Table 1. For preparing 1L of oil concentrate 800ml

of balanites oil was taken in beaker and 100ml of Sodium Lauryl Sulfate is added slowly. The mixture was stirred thoroughly using a mechanical stirrer up to when a homogenous liquid is formed. Then 50ml of Sulphur and 50ml of phenol were added to it and stirred well until a homogenous mixture was formed.
Thus the oil concentrate is prepared. This homogenous mixture can dissolve in water in all proportions and functions as oil in water emulsion. Table 1 shows the Cutting Fluids Formulation

Table 1 Cutting Fluids Formulation

Material	Function	Content (% volume/volume of fixed oil)
Balanites Seed Oil	Base oil	80
Sodium Lauryl Sulfate	Emulsifier	10
Phenol	Disinfectant	5
Sulphur	Extreme Pressure Agent	5

Preparation of the Emulsion Sample

Three emulsion samples were formed by varying the concentration of the balanites cutting fluid at 10%, 20%, and 30% in volume (designated as BCF-10, BCF-20 and BCF-30 respectively), remaining parts as water. For preparing the emulsion, the required quantity of water was taken with the balanites oil concentrate were stirred using a stirrer so that an oil in water emulsion was formed. The stirring continued for 5 minutes until a homogenous emulsion was formed. Fig.4 shows the sample of the developed cutting fluid. For the 10% balanites oil concentration, oil sample was mixed with water in the ratio 1:9 (i.e. 1 part of cutting fluid to 9 parts of water). The above procedure was repeated for 20% balanites oil concentration (i.e. 2 parts of cutting fluid to 8 parts of water) and 30% balanites oil concentration (i.e. 3 parts of cutting fluid to 7 parts of water). All the formulation and mixing were done at room temperature.

Figure 4: Sample of the developed cutting fluid

Oil Yield of Balanites Seed Kernel

The percentage (%) yield of the oil is the ratio of the weight of extracted oil to the weight of the cake before extraction. The mathematical representation is given in equation (3):

$$\text{Percentage Yield} = \frac{weight\ of oil}{weight\ of\ sample} x\ 100 \qquad (3)$$

$$\text{Percentage Yield} = \frac{W1 - W2}{W2} X\ 100 \qquad (4)$$

Where $W1$ = weight of sample before extraction and $W2$ = weight of cake after extraction

The percentage oil yield of the balanites seed kernel using the mechanical extraction method is given in Table 2.

Physiochemical Analysis of the cutting fluid

To assess the effectiveness of the formulated balanites oil based cutting fluids (BCF-10, BCF-20 and BCF-30) and the conventional cutting fluid (CCF) which is the control sample, physical properties like density, viscosity, flash point, pour point and pH value were analyzed.
Properties of the sample cutting fluid BCF-10 (10% Balanites oil concentrate), BCF-20 (20% Balanites oil concentrate), BCF-30 (30% Balanites oil concentrate) and CCF (Conventional cutting fluid) were determined below

Determination of Density

Sample Preparation

500ml of the SampleBCF-10, BCF-20, BCF-30 and CCF each were measured and poured in the measuring cylinder.

Procedure

Hydrometer was used in testing the density of the Sample BCF-10, BCF-20, BCF-30 and CCF according to ASTM D1298-99 in the following steps:

i. The Hydrometer was lowered in to the Sample BCF-10 and allowed to settle.
ii. The hydrometer reading was recorded.
iii. The same procedure was repeated for Sample BCF-20, BCF-30 and CCF.
iv. The results of the densities are presented in Table 3.

Determination of Pour Point

Sample Preparation

50ml of the Sample BCF-10, BCF-20, BCF-30 and CCF each were poured in a beaker.

Procedure

The Beaker, Cooling bath and a Thermometer were used in testing the pour point of the Sample BCF-10, BCF-20, BCF-30 and CCF according to ASTM D97-17b and the procedure is as follows:

i. The Sample BCF-10was cooled inside a cooling bath to allow the formation of paraffin wax crystals
ii. At 0ºC and for every subsequent 3°C the beaker was removed and tilted to check for surface movement.
iii. When the surface does not flow when tilted, the beaker was held horizontally at an interval of 5 sec and it was repeated for every 3ºC added to the corresponding temperature.
iv. The Sample temperature was measured the moment when the surface start sagging.
v. The temperature was recorded.
vi. The procedure was repeated for the SamplesBCF-20, BCF-30 and CCF.
vii. The results of the pour point are presented in Table 4.

Determination of Flash Point

20ml of the Sample BCF-10, BCF-20, BCF-30 and CCF were introduced in to a metallic cup. A closed fitting lid is fitted to the top of the cup.

Procedure

Pensky Martens Flash Point Tester was used in testing the flash point of the Sample BCF-10, BCF-20, BCF-30 and CCF according to ASTM D93-20 and the procedure is as follows:

i. The sample BCF-10 in the cup was heated and stirred.
ii. Apertures are then opened in the lid to allow air into the cup.
iii. The ignition source was then dipped into the vapors to test for flash point.
iv. Then the temperature was recorded.
v. The procedure was repeated for the SampleBCF-20, BCF-30 and CCF.
vi. The results of the flash point are presented in Table 5.

Determination of pH Value

Sample Preparation

100ml of Sample BCF-10, BCF-20, BCF-30 and CCF each were poured in to a beaker. A digital pH meter was connected to the electrode and a protective cap was removed.

Procedure

The digital pH meter was used to determine the pH value of Sample BCF-10, BCF-20, BCF-30 and CCF according to ASTM D664-04 and the procedure is as follows:

i. The tip of the electrode to the pH meter was immersed in the Sample BCF-10 to be tested.
ii. It was stirred gently and waited for a stable reading.
iii. The pH value was recorded.
iv. The procedure was repeated for Sample BCF-20, BCF-30 and CCF
v. The results of the pH value are presented in Table 6.

Determination of Viscosity

Sample Preparation

200ml of Sample BCF-10, BCF-20, BCF-30 and CCF each were poured in a beaker and was heated at 40ºC and 100°C respectively on an Electric heater. Rotor 2 sensor was selected and screwed anti-clockwise onto the connector. The lifting button was turned to slowly immerse the rotor 2 sensor into the fluid inside the beaker until the mark on the rotor 2 sensor is aligned with the fluid level.

Procedure

The DV-E Viscometer was used to determine the viscosity of the Sample BCF-10, BCF-20, BCF-30 and CCF at 40°C and 100°C according to ASTM D2270-93. The procedure is as follows:

i. The Sample BCF10 in the beaker was placed under the Viscometer.
ii. The power switch was turned ON, on the back of the instrument and now the instrument is on standby.
iii. The start button on the panel was pressed-on to initiate testing.
iv. The display value was allowed to be stable before it was recorded.
v. The procedure was repeated for the Sample BCF-20, BCF-30 and CCF.
vi. The results of the viscosities are presented in Table 7.

Performance and Evaluation of Cutting Fluids

The main objective of the present work is to experimentally investigate the role of balanites oil based cutting fluid in order to conduct heat away from the cutting zone in straight turning of mild steel with HSS tool at different spindle speeds, depth of cut and feeds combinations as compared to conventional mineral oil in machining.

Turning Process

The turning experiment was carried out on a center lathe machine (Model COLCHESTER Mascot 1600). The work piece of 50mm diameter and length of 160mm was inserted into a 3-jawchuck and the jaws were tightened by the chuck key until the jaw gripped the work piece tightly. The HSS Tool was tightly clamped in the tool holder for machining the work piece. The angle of the tool holder was adjusted so that the tool was almost perpendicular to the side of the work piece. The cutting speeds was first set at 278rpm. The feed rate is adjusted in the lathe for 0.5 mm/rev with 1mm depth of cut. The process was repeated continuously until a certain diameter for the workpiece was reached. Cutting fluid was applied directly in cutting zone with a rubber container by flooding method. The diameter of the workpiece was also determined using a Verniercaliper. These steps were repeated at cutting speed of 370 and 459rpm with 1.5mm and 2.0mm depth of cut respectively for developed cutting fluid (BCF-10, BCF-20 & BCF-30) and the conventional cutting fluid (CCF). Each experiment was repeated three times and cutting temperature were measured at regular interval of turning operation with the aid of digital infrared thermometer (make: BRAUN FHT 1000) having temperature range of up to 550°C and with optical resolution technique. Three different readings are taken from the cutting zone of the workpiece and the average value is taken as workpiece surface temperature. The data collected are shown in the Table 16 (see appendix 1). At the end of the processes the chips gathered for each procedure were then measured for thickness using a micrometer screw gauge and the surface generated on the work- piece was evaluated for surface roughness in (µm). The turning operation is depicted in Fig. 5 below:

Figure 5: The lathe machine turning operation

Chip Thickness

The chip samples were collected after machining with different spindle speeds with the developed cutting fluid (BCF-10, BCF-20 and BCF-30) and the conventional cutting fluid (CCF). The form and color of all those chips were watchfully examined and noted down. The thicknesses of the chips were repeatedly measured using the micrometer screw gauge and the corresponding chip thickness ratio was calculated using equation (3).

IV. Results

The result of the analysis is presented below

Oil Extracted from Balanites Seed

Table 2 showed the percentage of oil yield from the balanites seed kernel. It was observed that 1kg mass of seed kernel yielded 675g/kg of cake and 325g/kg of oil after mechanical extraction method. The percentage of oil yielded was then calculated to be 48.2%.

Table 2: Percentage Oil Yield of the Balanites Seed

Mass of seed Kernel (W1) (kg)	Mass of cake after Extraction (W2) g/kg	Oil Yield (W1-W2) g/kg	Percentage Yield of Oil (%)
1	675	325	48

Table 3 showed the density of the developed cutting fluid (BCF-10, BCF-20 & BCF-30) and conventional cutting fluid (CCF). The result shows that cutting fluid BCF-10 and BCF-20 has higher density of 0.96g/ml and 0.94g/ml compared to CCF with 0.92g/ml. However, BCF-30 recorded the least density 0.91g/ml.

Table 3: Density of Cutting Fluid Sample BCF-10, BCF-20, BCF-30 and CCF

Trials	BCF-10(g/ml)	BCF-20(g/ml)	BCF-30(g/ml)	CCF(g/ml)
1.	0.95	0.94	0.91	0.93
2.	0.97	0.92	0.91	0.91
3.	0.96	0.95	0.90	0.92
Avg.	0.96	0.94	0.91	0.92

Table 4 showed the pour point of the developed cutting fluid (BCF-10, BCF-20 & BCF-30) and conventional cutting fluid (CCF). The result indicates conventional cutting fluid (CCF) has the lowest pour point of -38°C compared to the developed cutting sample BCF-10, BCF-20 and BCF-30 with 9°C, 5°C and 3°C respectively.

Table 4: Pour Point of the Cutting Fluid Sample BCF-10, BCF-20, BCF-30 and CCF

Trials	BCF-10(°C)	BCF-20(°C)	BCF-30(°C)	CCF(°C)
1.	9	6	3	-38
2.	8	5	4	-38
3.	9	5	3	-38
Avg.	9	5	3	-38

Table 5 showed the flash point of the developed cutting fluid (BCF-10, BCF-20 & BCF-30) and the conventional cutting fluid (CCF). The test result indicates developed cutting sample BCF-30 has the highest average flash point of 280°C then followed by the conventional cutting fluid (CCF) with 225°C and the other developed cutting fluid sample BCF-10 BCF-20 were found to be 205°C and 225°C.

Table 5: Flash Point of the Cutting Fluid Sample BCF-10, BCF-20, BCF-30 and CCF

Trials	BCF-10(°C)	BCF-20(°C)	BCF-30(°C)	CCF(°C)
1.	205	215	280	255
2.	210	235	285	245
3.	200	225	290	255
Avg.	205	225	285	252

Table 6 showed the pH value of the developed cutting fluid (BCF-10, BCF-20 & BCF-30) and the conventional cutting fluid (CCF). The result indicates that developed cutting fluid sample BCF-30 has highest average pH value of 9.20 then followed by cutting fluid sample BCF-20 with 9.0, the least pH value was recorded from conventional cutting fluid sample CCF with 8.03.

Table 6: pH value of the Cutting Fluid Sample BCF-10, BCF-20, BCF-30 and CCFF

Trials	BCF-10	BCF-20	BCF-30	CCF
1.	8.12	9.01	9.20	8.03
2.	8.11	9.0	9.20	8.04
3.	8.09	9.02	9.21	8.02
Avg.	8.11	9.0	9.20	8.03

Table 7 showed the viscosity of the developed cutting fluid (BCF-10, BCF-20 and BCF-30) and conventional cutting fluid (CCF). The test result indicates that the developed cutting sample BCF-30 has the highest average viscosity of 29.3cP at 40°C then followed by the conventional cutting fluid (CCF) with 25.4cP and the other developed cutting fluid BCF-10 and BCF-20 were found to be 23.2cP and 24.6cP respectively.

Table 7: Viscosity of Cutting Fluid Sample BCF-10, BCF-20, BCF-30 and CCF at 40°C.

Trials	BCF-10(cP)	BCF-20(cP)	BCF-30(cP)	CCF(cP)
1.	23.5	25.2	29.4	24.5
2.	22.5	24.0	28.7	25.8
3.	23.5	24.5	29.8	25.8
Total Av.	23.2	24.6	29.3	25.4

Table 8 shows the comparison result of the average values of the properties of developed cutting fluid sample BCF-10, BCF-20, and BCF-30 with the conventional cutting fluid CCF with respect to density, pour point, flash point, pH value and viscosity.

Table 8: Summary of the average properties of developed cutting fluid (BCF-10, BCF-20 & BCF-30 and conventional cutting fluid (CCF)

Metal cutting fluid	Density (g/ml)	Viscosity 40°C (cP)	Flash Point (°C)	pH	Pour Point (°C)	Emulsion Stability
BCF10	0.96	23.2	205	8.11	9	Good
BCF20	0.94	24.6	225	9.0	5	Good
BCF30	0.91	29.3	285	9.20	3	Good
CCF	0.92	25.4	250	8.03	-38	Excellent

Table 9 showed the effect of spindle speed on surface roughness at constant feed rate of 0.5rev/min and 1.5mm depth of cut. The test result indicates the developed cutting fluid sample BCF-10 has the least average surface roughness value of 2.50mµ compared to the conventional cutting fluid sample CCF with 2.87mµ. In addition, the result also reveal that surface roughness value decreases with increase in spindle speed.

Table 9: Surface roughness under varying spindle speed at constant feed rate of 0.5rev/min and 1.5mm depth of cut

No. of Trial	Spindle Speed N (rpm)	Average surface Roughness Ra (µm)			
		BCF-10	BCF-20	BCF30	CCF
1	278	2.80	2.95	3.25	3.00
2	370	2.40	2.90	3.05	2.85
3	495	2.30	2.85	2.95	2.75
	Avg.	2.50	2.90	3.08	2.87

Table 10 showed the effect of feed rate on surface roughness at constant depth of cut of 1.5mm and spindle speed of 370rpm. The test result reveal that as the feed rate increases, the surface roughness value also increases.

Table 10: Surface roughness under varying feed rate at constant spindle speed of 370 rpm and depth of cut of 1.5mm

No. of Trial	**Feed rate (rev/min)**	**Average surface Roughness Ra (µm)**			
		BCF-10	**BCF-20**	**BCF30**	**CCF**
1	0.5	1.70	2.15	2.45	2.34
2	0.75	1.80	2.35	2.60	2.50
3	1.05	2.0	2.65	2.70	2.65
	Avg.	1.83	2.39	2.58	2.50

V. Conclusion

This study Analyses the performance effect of Balanites oil as cutting fluid in the turning of mild steel with High Speed Steel (HSS) cutting tool based on surface Temperature, Surface roughness and Chip thickness were performed and the obtained results were compared with those of conventional (control sample) cutting fluids. The following conclusions were drawn from the analysis of the results:

i. In all the formulations, the developed Cutting fluids sample BCF-10 and BCF-20 showed the best surface cooling characteristics and lower surface roughness at high speed and lower chip thickness formation, even better than the cutting fluid sample CCF (control sample) cutting fluids.
ii. An increase in the spindle speed decreased the surface roughness value of the workpiece. The least surface roughness was achieved at spindle speed of 495rpm.
iii. The cooling property of the cutting fluid sample BCF-10 and BCF-20 are comparable with that of conventional cutting fluid (CCF), as shown by the narrow temperature difference between the values obtained using developed cutting fluid(BCF-10, BCF-20) and that of control sample (CCF).

The chips thickness formed using the formulated cutting fluid BCF-10 and BFC-20 was highest, probably due to its better lubricating ability, especially at elevated temperature. This allows easier and deeper penetration of cutting tool into workpiece and better metal removal rate.

It is recommended that the Balanites oil-based cutting fluid formulated in this research should be experimented with other machining processes, e.g. milling, drilling, etc

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