Local Content Utilization Through Material Processing Practices for Industrial and Machine Tools Processes Application

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ABSTRACT: *The research titled local contents utilization through material processing practices for industrial and machine tools processes application considered locally available plants whose oil rich seeds were mobilized, primed and processed to extract the oils from the seeds. The plants sampled for the research are Shea Butter Tree from which Shea Butter Oils (SBO) was obtained, Cashew Plant from which Cashew Nut Oil (CNO) was obtained and Monkey Bread Plant from which Monkey Bread Seed Oil (MBSO) was obtained. The oils so extracted were used as base oils to formulate cutting fluids and were used in turning of AISI 1027 steel. To do that, the oils were first mixed with water in an appropriate ratio separately. The oil – water mixtures were finally blended with the necessary cutting fluids additives to obtain cutting fluids; Shea Butter Oil Cutting Fluid (SBOCF) Cashew Nut Oil Cutting Fluid (CNOCF and Monkey Bread Seed Oil Cutting Fluid (MBSOCF). Their performances (corrosion and heat dissipation tendencies) and other characteristics were evaluated and compared with that of a mineral oil based cutting fluid (control sample). Prior to machining, the acidities viscosities and flash points of the cutting fluids were measured. The metallic work piece was machined with the prescribed machining parameters. During machining, the tool – work interface temperatures were recorded using digital thermocouple. The performances in terms of heat removal from the tool – work interface was best achieved by SBOCF being local plants oil cutting fluid attaining a temperature of 36^oC at the highest Spindle speed (N) of 1050rpm and also the same SBOCF proved to be the safest from fire hazard with the highest flash point of 260^oC. They (local plants based oils) have the least tendencies to corrode metallic surfaces having the acidic values of 1.47g/dm^3, 2.50g/dm^3 and 2.45g/dm^3 as against that of the control sample standing at 3.99g/dm^3. MBSOCF has the best viscosity at 40^oC and 80^oC being 98.88cp and 35.83cp. From the foregoing, it can be concluded that local plant seed oils can be used in the production of cutting fluids for machining operations. Local plant oils cutting fluids can then conveniently substitute the conventional (mineral oil based) cutting fluids for all machining operations under various operating conditions. It is recommended that more efforts should be put into researches in the use of plant (bio) oils as cutting fluids since they have been proved to have good prospects.*

KEYWORD*s*: corrosion, cutting fluids, heat, local contents, machine tools processes, material processing and turning.

INTRODUCTION

Local Contents Utilization through Material Processing Practices for industrial and Machine Tools Processes Application basically has to do with Oil Extraction from locally available plant Nuts and seeds; Shea Butter Nut (SBN) from which Shear Butter Oil (SBO) was obtained, Cashew Nut (CN) from Cashew Nut Oil (CNO) and Monkey Bread Seed (MBS) from Monkey Bread Seed Oil (MBSO) and the formulation of cutting fluids from these oils to be used in machining of AISI 1027 steels. The performances in terms of heat dissipation and corrosion tendency of the cutting fluids on the steel samples when machined with the cutting fluids will be evaluated relative to that of a control sample (as purchased). Besides, other characterizations (flash point and viscosity) of the formulated cutting fluids and the optimum machining parameters (Spindle speed-N, Depth of Cut-DC and Feed Rate-FR) for machining processes will determined. The Spindle Speed (N - varying), Depth of Cut (DC-Varying) and Feed Rate (FR – constant) are the independent variables for the research while the average temperatures (Tav) is the dependent (Ayodeji et al.,2015).

The machining processes cutting fluids used for machining processes application are mostly mineral oils based (Tumba 2015). This research is intended to formulate mechanical machining cutting fluids from locally available oil rich plant seeds to be used in our mechanical machining workshops. This could substitute the conventional expensive cutting fluids which are not easy to come by in most of our Technological based Educational Institutions. In technological based institutions, machine tools processes form the core course offered by intending technicians, technologists and engineers especially in the field highly related to mechanical engineering and the use cutting fields for machining cannot be overemphasized (Tumba, 2015).

Locally available Plant seeds of our nation (Nigeria) are not maximally utilized for the benefit of the citizens. The seeds or nuts of our economic trees such as Shea Tree, Cashew and Baobab (Monkey bread seed) are laying mostly unused. Many people mostly villagers extract Baobab and Cashew oils to be used as cooking oil; Mahogany oil is also extracted and used for medicinal purposes or local body lotion on a very small scale. The extracts of the plants can be used to a larger extent in the formulation of cutting fluids, saponification and other related products (Parare and Ahav, 2015).

Shea Butter oil is a vegetable oil obtained from the seeds of a tree commonly known as Shea tree (Vitellaria paradox) which is a tree of the Sapotacea family (World Agro-forestry Centre). It is an African indigenous tree. It grows naturally in the wild in the dry Savannah belt of West Africa. The Shea fruit consists of a thin, tart nutritious pulp that surrounds a relatively large, oil-rich seed from which the Shea nut oil is extracted (Parare and Ahav 2015).

The properties of vegetable oils which enhance their performance in machining operations include the presence of fatty acids, surface active ingredient such as stearic acid and halogen such as chlorine which help to reduce surface energy and improve its wetting power or oiliness (Obi et-al, 2013). It has been shown that the coefficient of friction reduces as cutting speed increases when Shea butter is used as metalworking fluid.it was therefore concluded that Shea butter is effective in reducing cutting force during cylindrical machining due to enhance lubricating ability of the oils on account of their high molecular weights (Ojolo, et-al, 2008).

Baobab is an African tree having an exceedingly thick trunk and fruit that resembles a gourd and has an edible pulp called monkey bread. The tree also called monkey bread tree has its Botanical name as Adansonia Digitata. The monkey bread (MB) is embedded in an oval-shaped, hard, stiff and hairy shell that hangs on the branches of the tree. Right inside the shell, the monkey bread is arranged in layers and supported by strong fibers. The monkey bread grows outside right on the seed. The seed has a good oil content which is extracted for many purposes (Erebor, 2003). The oil of this contains high glycerides which gives it the property of high lubricity even when blended with some additives to form cutting fluids (Kuram and Ozcelik 2013).

Cashew is a tropical American evergreen tree bearing kidney-shaped nuts that are edible only when roasted. The family also includes poison ivy, poison oak, poison sumac, mango, the pistachio and the smoke tree The cashew native to America is now widely cultivated in Asia (especially India) and Africa notably for its nuts and other products. It grows as high as 12m (40ft) and has leathery oval leaves. The fragrant, reddish flowers grow in clusters and the pear-shaped fruit called cashew apples are reddish or yellowish. At the end of each fruit is a kidney-shaped ovary, the nut with a hard double shell. Between the shells is a caustic, black oil that can be removed by a difficult roasting process; the oil is used in making plastics and varnish. Cashew nut contains very high percentage of oil content which is being extracted for many purposes and which is the sole concern of this research (Erebor, 2003).

The natural relevance possessed by our plants are not being fully explored or maximized due limitation in knowledge and hence for time immemorial these plants had remained ignorantly unbeneficial. However, after some time the oil rich seeds of some of the local trees including those sampled for the research began to be used; Shea Butter (SBO) and Cashew Oils (CNO) were extracted to be used as cooking oils, while Monkey Bread Seed Oil (MBSO) was rarely extracted despite the fact that the seed is oil rich (Badau et al., 2016). Mineral or fossil oil based cutting fluids are generally expensive and not environmentally friendly. They pose a very serious problem of disposal since they are not bio-degradable.

Machine processes Cutting fluid is a type of coolant and lubricant designed specifically for metal working processes and these could be in the form of oils, oil-water emulsions, gels, pastes, aerosols (mists), air (N_2) or other gases (CO_2). However, cutting fluids are more specifically classified into straight oils, soluble oils, semi-synthetic and synthetic fluids. (Saleem, et al., 2013).The primary functions of a cutting fluid are as a coolant and lubricant. Secondarily, it flushes away chips and other metal particles from the tool/work interface and as well enhances protection against corrosion (Yakubu and Bello, 2015).

Metal cutting operations generate heat from work done against friction at the tool/work interface and also work done against the material particles of the work piece; this has adverse effects on the tool and the work piece as the surrounding air is insufficient to dissipate the heat generated as fast as is required (Obi et al., 2013). It therefore becomes imperative that a means of reducing the rate of heat generation as fast as possible, at the lowest cost and with little or no environmental effects should be devised. Over the years, diverse ways and means of cooling and lubricating the cutting tool/work interface have been employed leading to the evolution of what today are known as cutting fluids (Sharma, 2015).

Properties of good cutting fluids, therefore, include the ability to keep tool/work piece interface at a stable temperature, maximize life of cutting tool by lubricating the working edge and reducing thermal deformation (Badau et al., 2016). It has to be chemically inactive in order not to react with the work piece material, ensures the safety of those handling it against toxicity, bacterial and fungal infections, safe to the environment upon disposal, and prevent the rusting of the tool, work and machine parts.

Vegetable or animal oils (fixed oils) which are non-volatile which do not evaporate at room temperature and can easily be sponified (Baba et al., 2018). Water was the first cutting fluid used in cutting steels, animal fats and oils from plant sources were also used before the invention of fossil oils which later took over for many years. Researches or experiments revealed that fossil oils when emulsified in water and mixed with some additives improved upon the cutting properties of the cutting fluids by combining the best qualities in fossil oils and water to produce better metal working fluids. That led to the emergence of the soluble oil. Water-soluble cutting oils, because of their good thermal conductivities have the ability to dissipate heat more readily than neat cutting fluids (Demirbas 2013). Fixed oils based cutting fluids eliminates the heat generated at tool-work interface easily and gives excellent lubrication thereby minimizing friction, wear, improving tool life and surface finish (Lawan et al., 2007).
According to Kuram, 2013, “Vegetable oils consist of Triacylglycerides otherwise called trigylcerides which are glycerol molecules with three long glycerol molecules with three long chain fatty acids attached at the hydroxyl groups via ester linkages. It is this triglycerides structure of vegetable oils that provides the good lubrication tendency. Vegetables oils perform better than other oils due to the following reasons.

MATERIALS AND METHODS

Materials

Machine steel blank of length 650mm and 40mm, various plant seeds, oil extractor, SBO, MBSO, CNO, phenol, sulphur, washing soda and water.

Tool/Equipment

Machine tools, Oswald viscometer, thermocouple, stop watch, weighing balance, measuring cylinder, beakers, pipette, burette and vernier caliper.

Methods

Seeds Mobilization and Priming

The seeds of the various plants will be mobilized and primed for oil extraction.

Oil Extraction

The mobilized seeds will be subjected to oil extraction processing to extracts the oils contained in the oil rich seeds.

Machine Processing Cutting Fluids Formulation

Machine Processing Cutting Fluids will be formulated from the plant seeds oils for machine processes application.

Machining and Temperature Measurement

Work piece will be machined by finish turning operation with different machining parameters at different levels using all the cutting fluids including the control sample. This is meant to test the performance of the formulated cutting fluids. AISI 1028 Steel samples of lengths 650mm and cross-sectional diameter of 40mm were straight turned between centers on E3N-01 lathe machine using High Speed Steel (HSS) tools of the same tip configurations. The control sample and all other cutting fluids will be handled with different turning tools. Every experiment would be ran for at least ten (15) minutes. Cutting fluid was automatically supplied to dissipate the heat generated at the tool/work interface. The temperature at the tool/work interface was measured with the aid a digital thermocouple (Tumba, 2017).

Experimental Design

Factorial design will be used for the research expressed as

$$l^f \times n$$

Where; $l = levels, f = factors \ and \ n = number \ of \ replications$

The machining parameters will be taken at four (4) levels, two factor and will be replicated twice. This means that, eight (8) experiments will be run for each cutting fluid and thirty two (32) for the entire research. Machining parameters and levels are shown in Table 1.

Table 1: Levels of Machining Parameters

Sample	N (rpm)	DC (mm)	FR (mm/rev)	Tav (°C)
A (Control Sample)	750	0.5	0.125	
	850	1.0	0.125	
	950	1.5	0.125	
	1050	2.0	0.125	
B.SBOCF (Shea butter oil cutting fluid)	750	0.5	0.125	
	850	1.0	0.125	
	950	1.5	0.125	
	1050	2..0	0.125	
C.MBSOCF(Monkey bread seed oil cutting fluid)	750	0.5	0.125	
	850	1.0	0.125	
	950	1.5	0.125	
	1050	2.0	0.125	
D.CNOCF (Cashew nut oil cutting fluid	750	0.5	0.125	
	850	1.0	0.125	
	950	1.5	0.125	
	1050	2.0	0.125	

Corrosion tendency determination

The acidic value of all cutting fluids with the control sample inclusive will be determined by titration. 0.1M of NaOH was used as a base for the titration with about 10ml of each sample and phenolphthalein as an indicator. The value of the acid content will tell which one will be more susceptible to corrode the work piece (Lawal et al, 2007).

Viscosity Determination

The viscosities of all cutting fluids will be determined using Ostwald apparatus and Ostwald equation (Tumba, et al., 2017)

RESULTS AND DISCUSSIONS

Corrosion Tendencies of Cutting Fluids

The Acidities of all the cutting fluids as determined by titration are tabulated in Table 2. The acidity of the cutting fluid determines its corrosion tendency.

Table 2: Acidity of Cutting Fluids

Cutting Fluids	Acidity (g/dm^3)
A (Control Sample)	3.99
B.SBOCF (Shea Butter oil Cutting Fluid)	1.47
C. MBSOCF(Monkey Bread Seed Oil Cutting Fluid)	2.36
D.CNOCF(Cashew Nut Oil Cutting Fluid)	2.45

The Acidities of all the cutting fluids are presented in Table 2Shea Butter Oil Cutting Fluid (SBOCF), Monkey Bread Seed Oil Cutting Fluid (MBSOCF) and Cashew Nut Oil Cutting Fluid (CNOCF) with the acidic values of 1.47g/dm^3, 2.36g/dm^3 and 2.45g/dm^3 respectively have the least tendency to corrode metallic surfaces compared to the control sample. This is similar to the result obtained by Lawal at al 2007. The control sample has the tendency to corrode metallic surface as its acidic value stands at 3.99g/dm^3.

Work – Tool Interface Temperatures

The work piece was turned with the prescribed machine Process parameters at all levels using all the cutting fluids and the Average work – tools interface temperatures as recorded by a digital thermocouple is presented in Table 3.

Table 3: Average Tool –Work Interface Temperature

Sample	N (rpm)	DC (mm)	FR (mm/rev)	Tav (ºC)
A.CS (Control Sample)	750	0.5	0.125	30
	850	1.0	0.125	32
	950	1.5	0.125	35
	1050	2.0	0.125	37
B.SBOCF (Shea butter oil cutting fluid)	750	0.5	0.125	28
	850	1.0	0.125	29
	950	1.5	0.125	32
	1050	2..0	0.125	34
C.MBSOCF(Monkey bread seed oil cutting fluid)	750	0.5	0.125	29
	850	1.0	0.125	30
	950	1.5	0.125	33
	1050	2.0	0.125	36
D.CNOCF (Cashew nut oil cutting fluid	750	0.5	0.125	29
	850	1.0	0.125	30
	950	1.5	0.125	34
	1050	2.0	0.125	39

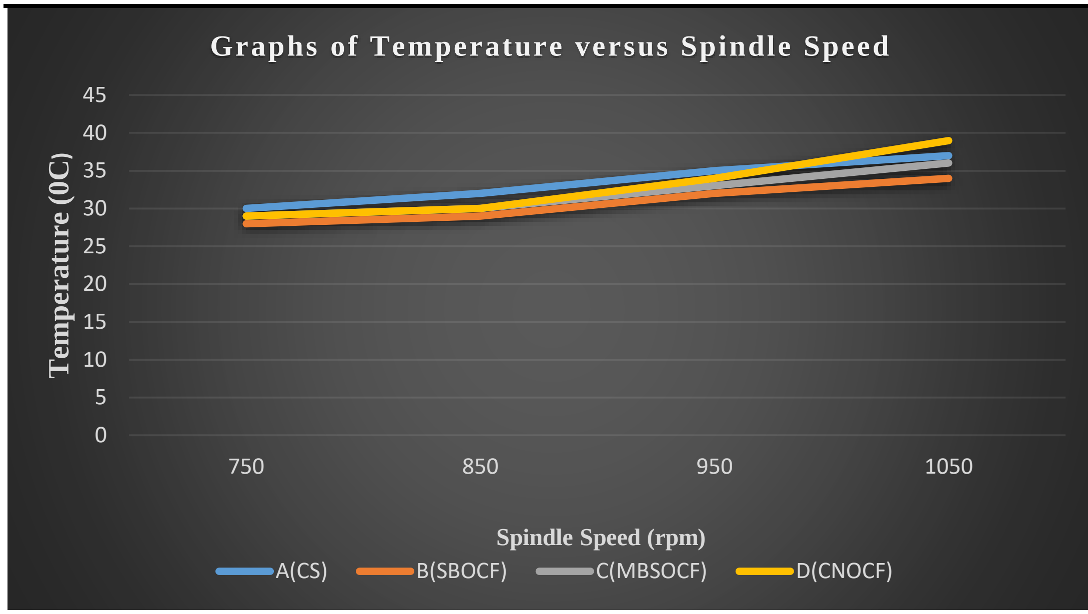

Figure 1: Graphs of Temperature versus Spindle Speed

The work piece being AISI 1028 steel was straight turned between centers of lathe machine using single point cutting tool (HSS) within the range of machining parameters specified by ASTM for finish turning operations. To measure heat generated using digital thermocouple during the turning operation the cold junction of the thermocouple was placed in contact with a freezing ice while the tip in contact with the tool – work interface and are moved together automatically along the machine bed as the machining is done as suggested by Badau et al 2016.

The entire experiment was carried out as designed using all the cutting fluids. From Table 3 and Figure 1 it can be seen that for all cutting fluids, the tool –work interface temperatures increase with increase in cutting speed. This is in consonant with a report by Badau et al 2016. Besides, SBOCF being locally available vegetable oil based cutting fluid performs better in terms of heat removal than all the cutting fluids including the control sample which is a mineral oil based cutting fluid contrary to the work by Kuram and Ozcelik 2013. This may be due to the presence of triglycerides which are glycerol molecules in vegetable oils and also having greater wettability as suggested by Kuram and Ozcelik 2013.This may also be due to good thermal properties (specific heat and thermal conductivity) possessed by vegetable oils (Ayodeji et al., 2015) This is followed by MSOCF attaining the highest temperature of 32^{o}C at the Spindle speed of 1050rpm. That means that the two cutting fluids could compete favorably and they could be synergized to get the best result as suggested by Lawal et al (2007).

Viscosities of Cutting Fluids

The viscosities of all the cutting fluids were determined at 40^{o}C and 80^{o}C and are shown in Table 4.

Table 4: Viscosities of Cutting Fluids

Cutting Fluids	Viscosities at 40°C (Cp)	Viscosities at 80°C (Cp)
A (Control Sample)	103.16	55.56
B.SBOCF (Shea Butter oil cutting fluid)	101.14	70.77
C.CNOCF(Cashew nut oil cutting fluid)	134.00	87.00
D.MBSOCF (Monkey bread seed oil cutting fluid)	98.88	35.83

Viscosity as an oil property has a significant impact on machining processing as reported by Badau et al (2016). Vegetable oils have a high natural viscosity as the machining temperature increases as reported by Badau et al (2016) and Kuram and Ozcelik (2014). The viscosity of vegetable oils drops more slowly than that mineral oils as the temperature falls, vegetable oils remain more fluid than mineral oils facilitating quicker drainage from chips and work pieces. The higher viscosity index of vegetable oils ensures that vegetable oils will provide more stable lubricity across the operating temperature range. Vegetable oil molecules are quite homogeneous in size but mineral oil molecules vary in size. Consequently, the properties of mineral oil such as viscosity, boiling temperature are more susceptible to variation. Vegetable oil has higher boiling point and greater molecular weight and this results in less loss from vaporization and misting. The viscosities of all the cutting fluids are presented in table 4. The results places MBSOCF first in terms of viscosity even at higher temperature of 80°C dropping to 35.83Cp. This is followed by SBOCF dropping to a value of 70.77Cp at 80°C from 101.14Cp at 40°C confirming the statement of Kuram and Ozcelik 2014.

Flash Points of the Cutting Fluids

Table 5 shows the Flash points of all the cutting fluids.

Table 5: Flash Points of Cutting Fluids

Cutting Fluids	Flash points (°C)
A (Control Sample)	228
B.SBOCF (Shea Butter oil Cutting Fluid)	260
C.CNOCF(Cashew nut oil cutting fluid)	211
D.MBSOCF (Monkey bread seed oil cutting fluid)	244

The cutting fluids flash points are presented in table 5. This shows that all the cutting fluids are very safe for use without the risk of fire hazard. SBOCF has the highest flash points (260°C) and this proves to be the safest in use. The flash points for all mineral oils is 226°C as reported by Dolan 1992.

CONCLUSION AND RECOMMENDATIONS

Conclusion

Locally available vegetable oils based cutting fluids formulated from Shea Butter, cashew oils and Monkey Bread seed oils were used in the turning of AISI 1028 steel and their performances were relatively evaluated alongside that of a control sample of crude petroleum (mineral oil based) cutting fluid. From the experiments conducted, it can be concluded that plant oils can be used in the production of cutting fluids which serve as an alternative coolants and lubricants in machine tools processes. SBOCF was found to be the best among the cutting fluids in conducting heat away from tool-work piece interface. It was followed by MBSOCF.

Recommendations

With the knowledge of the fact that no research work can be considered conclusive in itself, the following are recommended:

1. More efforts should be put into research in the use of bio-oils as cutting fluids since they have been proved to have good prospects.
2. The cutting fluids formulated in this research work should be experimented in other machining processes, e.g. milling, drilling, etc.
3. A research should be undertaken to ascertain the best compositional ratio of the base oil to the other additives for best performance in each of the bio-oils used in this work.
4. Local contents research initiative drive should be encouraged not only in the area of machining but in all the sectors of manufacturing industries

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