

FORMULATION OF SELECTED ANIMAL FATS AND VEGETABLE OILS AS POTENTIAL METAL CUTTING FLUIDS - PART 1: PRELIMINARY CHARACTERIZATION

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Acronyms: LCF – Lard cutting fluid; GCF – Groundnut oil cutting fluid (*Arachishypogaea*); TCF – Tallow cutting fluid; PKCF – Palm kernel cutting fluid (*Elaeisguineensis*); POCF – Palm oil cutting fluids (*Elaeis guineensis*); MCF – Mineral oil cutting fluid.

ABSTRACT: *Conventional mineral based oils currently being used as metal cutting fluids are not environmentally friendly and pose health challenges to users. Therefore, there is need to formulate alternate cutting fluids that will not pose such challenges. The objective of this study is to formulate and characterize some selected vegetable (groundnut oil, palm oil and palm kernel oil) and animal (pig fats and cow fats) oils, as metal cutting fluids. The vegetable and animal oils were formulated into cutting fluids following procedures from published articles. Thereafter, the formulated fluids were characterized in terms of pH, viscosity, fluidity, density and corrosiveness using their respective standards. Conventional mineral oil-based cutting fluid (MCF) was used as control in the study. The properties of the formulated fluids such as pH had an average value of 9, which is the standard value for most mineral based cutting fluids. Also, corrosion studies of the fluids showed that they cannot accelerate corrosion in machined components. This was evident from the results of the corrosive tests carried out, with corrosion rates ranging from 0.00040 mm/yr to 0.00082 mm/yr for all the sample fluids. The results for density of all the sample fluids was between 0.9110 g/cm³ to 0.9130 g/cm³, while that of viscosity at 100°C was between 7.32 cSt to 9.40 cSt. The results showed that the pH, density, viscosity and fluidity of the sample fluids recorded competitive values with that of the control fluid. The best sample fluid with respect to all the properties obtained and compared with the control fluid (MCF) was LCF. This was followed by GCF, TCF, PKCF and POCF respectively. Hence, based on the characterization parameters studied, it was deduced that the sample fluid; having shared closed values with the conventional or control fluids, can be employed in cutting fluid formulation, especially when fortified with complete additives used in conventional mineral oils.*

Key words: Mineral, cutting fluids, animal fats, vegetable oils, cutting tools.

1.0 INTRODUCTION

Developed parts of the world (say Europe and US) has instituted laws and regulations that significantly affect the formulation of metal working fluids (Bartz, 2001). Industries using these fluids are endlessly searching for better performing cutting fluids, which have to be formulated using certain quantity of various additives. More so, Industries, Employee Unions and Government, enforce the movements for a healthy and safe work environment, as well as disposal aspects influencing the global environment. These movements have already affected the formulation of cutting fluids in Europe and the US as follows: the removal of nitrite from cutting fluid composition and replacing diethanolamine short chained chlorinated paraffin (Bartz, 2001).

All these removals or replacements have to be realized with the goal not to affect adversely the performance of the metalworking fluids.

Cutting fluids are used in metal machining for variety of reasons and the result is to improve tool life, reduce work piece thermal deformation, improve surface finish and flushing away chips from the cutting zone (Bartz, 2001). In the 19th-century, machining practice was not unusual to using plain water. This was a simple practice used to keep the cutter tool cool, regardless of whether or not it provided any lubrication at the cutting edge or chip interface. When one considers that high-speed steel (HSS) had not been developed then, the need to cool the tool becomes very important.

Cutting fluids are employed widely in most machining processes. However, because of the damaging influences by some on the environment, their applications have been limited in machining processes. New approaches for elimination of cutting fluids application in machining processes have been examined in the past and “dry machining” was presented as an important solution (Sreejith and Ngoi, 2000). The development of new cutting tool materials also helped dry machining method to be a positive solution for cutting fluids applications. But the usage of cutting fluids has increased due to high production levels in the world. According to 1998 values, approximately 2.3×10^9 litres cutting fluids have been used in machining operations and its cost value was around \$2.75 Billion. North America had a big ratio Europe was in the third order after the Asian Continent (Glenn and Antwerpen, 1998).

Mineral oils have been in use as the traditional source of cutting fluids in machining a number of metals and alloys because of their suitable lubricating properties on both the workpiece and the cutting tools (Adegbuyi *et al.* 2010). However, there are now many challenges posed by using such oils as lubricants in most of today’s applications. Such challenges include, but not limited to the growing environmental concerns such as renewability and biodegradability (Lawal *et al.* 2012). Also, too much exposure or contact with it results to some health hazards. Vegetable and animal oil-based cutting fluids on the other hand, are environmentally friendly and do not pose any form of threat to health of the users. Recent studies have also shown that they have better lubricities than the mineral oil-based fluids (Adejuyigbe and Ayodeji, 2000).

1.1 OBJECTIVES

The objectives of this study were

1. To formulate cutting fluids from three (3) selected vegetable oils (palm oils, groundnut oils, palm kernel oils) and two animal oils (cow fats, pig fats),
2. To characterize the cutting fluids in terms of pH, viscosity, fluidity, corrosiveness, and density.

2.0 METHODOLOGY

This was divided into two (2) stages: cutting fluid formulation and cutting fluid characterization

2.10 Stage one: Cutting Fluid Formulation.

The palm oil, groundnut oil, palm kernel oil, pig fats (lard) and cow fats (tallow) were purchased from a local market in South west Nigeria.

The palm oil, groundnut oil, and palm kernel oil (PKO) were already in form of oil, waiting for the actual cutting fluid formulation.

The pig fats (lard) and cow fats (tallow) were washed and rendered into bits, and thereafter steamed without water in a pot for about 20 minutes. This process extracted the oil from the fatty tissues of both animals see (Fig. 2.0). The oily content was then sieved out and allowed to cool for about four minutes.



Figure 2.0: Tallow & Lard Preparation

The cutting fluids were then formulated following recommendations (see Table 2.1) by DeGarmo *et al* (1984), and Ibadode, 2001.

Table 2.1: Cutting Fluid Emulsion Formulation.

S/n	Material	Function	Content: %vol / vol of fixed oil.
1	Fixed Oil (Sample fluids)	Base Oil	80
2	Emulsifier (see Table 2.2 for composition)	Emulsification	10
3	Phenolphthalein solution (phenol)	Disinfectant, also removes odor.	5
4	Sulphur	Extreme pressure agent improves oxidative stability during usage at high temperature.	5

Table 2.2: Emulsifier Composition

Item	Composition
Sodium lauryl sulphate	0.5M
Nitrosol	0.5M
Sodium tripolyphosphate	0.5M
Sulphonic acid	0.5M
Calcium carbonate	0.5M
Water	5litres

After following the composition stated in Table 2.1, a high-speed blender was used to homogenize the mixture at room temperature for 15 minutes to get emulsions. The emulsions were then mixed in water in a ratio of 1:10 (Chapman, 1972) to get the cutting fluids.

2.20 Stage two: Fluids Characterization:

The fluids were characterized in terms of the following properties:

pH: This was obtained with a wagtech digital pH meter. The measurement was done in accordance to NIST 2009 standards for pH measurements with pH meters. Before measurement, the pH meter was calibrated with a standard buffer solution (solutions of weak acids, weak alkaline, mixed with their respective salts).

Viscosity, η : This was obtained with a viscometer (rapid visco analyzer with in-built temperature sensors). The measurement was done in accordance to ASTM D562-10 (2014) standard test for viscosity measurement with viscometers. The values were taken at 25°C and 100°C.

Fluidity, τ : This was computed directly from viscosity, i.e. the reciprocal of viscosity.

Density, ρ : This was obtained with a general-purpose hydrometer. The measurement was done in accordance to ISO 649-1: 1981 standard for density measurement with general purpose hydrometers.

Corrosiveness: This describes the protection of the machined components from corrosion after direct contact with the fluids during machining. Sizeable (20mm x 20mm) machined components made of mild steel was weighed with an electronic scale, and then immersed completely at room temperature in the test cutting fluids for 5days (120hrs). The components were then dried and weighed again, and the difference in weight was taken. Equation 1 by Fontana (1987) was then used to calculate the corrosion rates of the components.

$$CR = \frac{87.6 W}{\rho AT} \dots\dots\dots(1)$$

CR = Corrosion rate (mm/yr), W = Weight loss (g), ρ = Density of mild steel (g/mm³), A = Exposed area (mm²), T = Exposure time (yrs).

Cutting fluids colour, odour and solubility: These were done by physical inspection during the formulation process.

3.0 RESULTS AND DISCUSSIONS

The results are presented side by side with the control fluid (MCF) to know which sample fluids best compares well with it. From Table 3.1, it is seen that the fluids had a pH value of 9 on the average. These values represent the standard pH for conventional MCF. The value is also in line with those reported by Kuram *et al.* (2010) and Lawal *et al* (2011). Hence, the fluids will not accelerate or cause corrosion in machined components when applied as cutting fluid. This is also evident from the results of the corrosive tests conducted on the sample fluids, (Table 3.2), which showed that all the samples recorded low corrosion rates. It is however important to note that, components during a typical machining operation may not be exposed in the cutting fluids up to the exposure time (120hrs) used for the corrosive tests in this study. Hence, less exposure time, means little or no corrosion with respect to exposure or contact with the cutting fluid, since the corrosion rates will further be reduced, more than what was obtained.

Table 3.1 pH Properties of the Cutting Fluids

Sample Fluids	pH
LCF	8.98
TCF	8.95
POCF	9.10
GCF	8.96
PKCF	9.14
MCF	9.19

Table 3.2 Corrosive Properties of the Cutting Fluids

Sample Fluids	Corrosion rates (mm/yr)
LCF	0.00081
TCF	0.00082
POCF	0.00061
GCF	0.00082
PKCF	0.00040
MCF	0.00020

More so, the control fluid (MCF) had a density value of 0.9287 g/cm^3 at 25°C (Table 3.3). The formulated cutting fluids had their density values close to that of MCF. The values are also close to those reported by Lawal *et al.* (2011) and Kuram *et al.* (2010). This implies that the formulated fluids can aid machinability of the workpiece just like MCF.

Table 3.3 Density Properties of the Cutting Fluids

Sample Fluids	Density, ρ (g/cm^3) at 25°C
LCF	0.9127
TCF	0.9130
POCF	0.9132
GCF	0.9110
PKCF	0.9128
MCF	0.9287

The sample fluids also offered competitive fluidity values with that of the control. The samples fluidity (Table 3.4) at high temperature was close to that of the control fluid (MCF). MCF had fluidity value of 0.113 rhes at 100°C . LCF had the best fluidity values of 0.137 rhes at 100°C even when compared to the mineral oil (MCF). This means that even at temperatures above room conditions, the fluids can still flow to cover the entire machined metallic surface, thereby enhancing the cooling and lubricating capability.

Table 3.4 Viscosity and Fluidity Properties of the Cutting Fluids

Sample Fluids	Viscosity, η (cSt) at 25°C	Viscosity, η (cSt) at 100°C	Fluidity, χ (rhes) at 25°C	Fluidity, χ (rhes) at 100°C
LCF	81.39	7.32	0.012	0.137
TCF	86.12	9.36	0.012	0.107
POCF	89.10	9.56	0.011	0.105
GCF	80.51	8.89	0.012	0.112
PKCF	82.55	9.40	0.012	0.106
MCF	98.45	8.83	0.010	0.113

Table 3.5 shows the properties of the sample fluids physically inspected before and after emulsification. They were inspected during the formulation process.

Table 3.5: Physical properties (colour, odour, solubility) of the oil samples.

Samples	Properties	Before Emulsification	After Emulsification
Lard	Colour	Dark	Milky white
	Odour	Unpleasant, irritating	Slightly irritating
	Solubility in water	Insoluble	Soluble
Tallow	Colour	Dark	Milky white
	Odour	Unpleasant	Slightly irritating
	Solubility in water	Insoluble	Soluble
Palm oil	Colour	Red	Pale yellow
	Odour	Pleasant	Pleasant
	Solubility in water	Insoluble	Soluble
Groundnut oil	Colour	Gold	White
	Odour	Pleasant	Pleasant
	Solubility in water	Insoluble	Insoluble
Palm kernel oil	Colour	Pale yellow	Milky white
	Odour	Pleasant	Pleasant
	Solubility in water	Insoluble	Soluble

4.0 CONCLUSION

The study has shown the formulation and preliminary characterization of some animal (cow fats, pig fats) oils and vegetable (groundnut, palm oil, palm kernel) oils as metal cutting fluids. The oil samples were formulated successfully into cutting fluids following recommendations from some published articles. The properties considered for the characterization were few, reason why it was termed “preliminary characterization”.

The following conclusion can be drawn from the study:

1. The properties of the formulated fluids such as pH had an average value of 9, which is the standard value for most mineral based cutting fluids. Hence, they cannot accelerate corrosion in machined components.
2. This is also evident from the results of the corrosive test done.
3. For an exposure time of 120 hours (which is more than the machining time in which the fluid gets in contact with a workpiece in a typical machining operation), the formulated fluids recorded low corrosion rates on the machined components tested. This means that if they are fortified with anti-corrosion additives like the conventional mineral oil; their corrosion inhibiting properties will be improved.
4. The samples also had good fluidity values compared to that of the conventional fluids, which would make it maintain its lubricating effect at temperatures above room values.

Although the actual performance evaluation of the formulated fluid was not done in this study, it has been taken care of in the part II of the study. The best sample fluid with respect to all the properties obtained and compared with the control fluid (MCF) was LCF. This was followed by GCF, TCF, PKCF and POCF in the order which they have appeared respectively.

Hence, based on the characterization parameters studied, it was deduced that the sample fluids, having shared closed values with the conventional fluids, can be employed in cutting fluid formulation, especially when fortified with complete additives used in conventional mineral oils.

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