DEVELOPMENT OF ENVIRONMENTALLY FRIENDLY BIODEGRADABLE CUTTING FLUID FROM SOYA BEANS (GLYCINE MAX)

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(GLYCINE MAX)

BY

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JULY, 2015

DECLARATION

I hereby declare that this dissertation titled "**Development of Environmentally friendly Biodegradable Cutting Fluid from Soya Beans"** was done by me in the Department of Mechanical Engineering, Ahmadu Bello University Zaria, under the supervision of Prof. A.I. Obi and Prof. S. Y. Aku. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this work has been presented for another degree or diploma in any institution.

Samson EJEH	_____	_____
Name	(Signature)	(Date)

CERTIFICATION

This dissertation entitled "**DEVELOPMENT OF ENVIRONMENTALLY FRIENDLY BIODEGRADABLE CUTTING FLUID FROM SOYA BEANS (GLYCINE MAX)"** meets the requirement for the award of degree of Master of Science in mechanical Engineering of Ahmadu Bello University, Zaria, and is approved for its contribution to knowledge and literacy presentation.

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DEDICATION

This research work is dedicated to Almighty God who had been with us right from the start in time of difficulties and simplicities, pains and joy and finally crowing our effort at the end of the journey. And to my beloved father the late, Mr. Frederick Sunday Ejeh and my beloved mother, Mrs Esther Ejeh Ella. My beloved brothers: Ejeh junior, Innocent and Christian. My lovely sisters: Ada, Anna and Lucy.

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ABSTRACT

In this work, cutting fluid emulsion was developed from soya beans and the performance of the developed cutting fluid was evaluated by comparison with the conventional cutting fluid (control sample), using its ability to effectively perform as coolant during machining operation. The machining operation employed was the turning operation in which chips produced were collected and their surface finishes measured. The chips collected were evaluated for chip thickness ratio. Also, the temperature variations during cutting operation were measured using an infra- red gun thermometer. Temperature, surface finishing as well as chip formation rates using the developed cutting fluid under different cutting speed (rev/min), feed rate (mm/rev) and depth of cut (mm) was compared with that of the conventional cutting fluid. The average temperature of the work piece when developed cutting fluid was used as cutting fluid was 53.13 ^{o}C and that of the conventional cutting fluid was 54.7 ^{o}C. The result are very close, hence it shows better result in conducting heat away from cutting region. The developed cutting fluid gave an average high chip thickness of 0.446 mm while that of the conventional cutting fluid was found to be 0.316 mm. The high chip thickness of the developed cutting fluid is probably due to its better lubricating ability which allows easier and deep penetration of cutting tools. The average viscosity of the developed cutting fluid was found to be 31.1 poise at 29 ^{o}C, while the convectional cutting fluid was 47 poise at 29 ^{o}C. Low viscosity means high viscosity index, the developed cutting fluid has tendency to be fluid at higher temperature than the convectional fluid. In corrosion measurement, the developed cutting fluid shows no sign of corrosion; hence, the fluid has good ability to inhibit corrosion than the convectional cutting fluid.

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NOMENCLATURE

SYMBOL	DEFINITION
$\mathbf{A_O}$	Original Area (mm)
B	Width (m)
CLA	Centre Line Average (mm)
D	Diameter (mm)
$\mathbf{F_t}$	Normal force (N)
$\mathbf{F_S}$	Shearing force (N)
H	Peak height (mm)
HSS	High Speed Steel
L	Length (m)
r	tool nose radius (mm)
t	depth of cut (mm)
T	Temperature rise at tool-chip interface (^{O}C)
Φ	Shear Angle (^{O})
□	Clearance angle (^{O})
α	Rake angle (^{O})

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CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

The use of cutting fluids in metal cutting was first reported in 1894 by F. Taylor who noticed that cutting speed could be increased by 33% without reducing tool life by applying large amounts of water in the cutting zone (Ávila and Abrao, 2001). Cutting fluids increase tool life and improve the efficiency of the production systems providing both cooling and lubrication of the work surface.

Cutting fluids are used to reduce the negative effects of heat and friction on both tool and work piece. Cutting fluids produce three positive effects on the process: heat removal, lubrication on the chip–tool interface and chip removal (Lopez de Lacalle *et al.,* 2006). However, the advantages caused by the cutting fluids have been questioned lately, due to the several negative effects they have caused to in the environment and worker's health.

When inappropriately discharged, cutting fluids may damage soil and water resources, causing serious environmental impact. On the shop floor, machine operators may be affected by negative effects of cutting fluids, such as skin and respiratory problems (Lopez de Lacalle *et al*., 2006). In order to make the machining process more ecologically friendly, a near-dry application of lubricant have been accepted because of its environmentally friendly characteristics (Sokovic *et al*., 2001, Dhar *et al*.,2006 and Suda *et al.*,2004). But, depending on the machining process, to reduce or eliminate cutting fluids use is not possible. For these cases it is necessary to develop an alternative solution in order to avoid environment and heath damage.

The use of vegetable oils may make possible the development of a new generation of cutting fluids of high performance in machining combined with good environmental friendliness.

Interest in vegetable oil-based cutting fluids 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 (Woods, 2005). Although, they have many environmental benefits, vegetable oils are more susceptible to degradation by oxidation or hydrolytic reactions. Therefore, the correct selection of the vegetable substance, the pH of the resulting solution and its control are important issues (Woods, 2005).

1.2 Statement of the Problem

Cutting fluids based on minerals oils are normally used for their low costs and chemically stability. However, the present trend towards new types of cutting fluids based on vegetable oils is clearly justified by their higher biodegradability and lower environmental impact. Chemically based cutting fluids presently used have adverse effects on the operator and the environment compared to the environmentally friendly vegetable- based cutting fluids. The performances in areas of surface finish, chip thickness and temperature of these two types of oils (chemically based cutting fluid and vegetable- based cutting fluid) are similar. Issues of environmental pollution and hazard to workers have arisen and there is need to develop safe and efficient metalworking fluids which are environmentally friendly. (Lopez de Lacalle *et al*., 2006).

1.3 The Present Work

This present work is concerned with the development of a vegetable based cutting fluid using soya bean oil because of its availability and high fatty acid content which is responsible for the oiliness and lubricity, lubricant additive to enhance its performance for the machining process.

This product is tested in turning operations using mild steel to verify its performance.

1.4 Aim and Objectives of the Research

The aim of this work is the development of environmentally friendly biodegradable cutting lubricant from soya beans (*glycine max).*

The specific objectives of the research are:

i. Developing biodegradable cutting fluid from vegetable based oil (soya beans) that is environmentally friendly.

ii. Carrying out performance evaluation of the developed cutting fluid in turning operations based on the surface finish, chip thickness ratio, amount of heat generated during the machining operation and chemical properties (corrosion, pH values, acid value and viscosity) of the developed cutting fluid.

iii. Comparing the physiochemical properties of the developed cutting fluid to that of the conventional cutting fluid.

1.5 Scope of the Work

The work done cover the following areas;

i. Vegetable based cutting fluid was developed

ii. Determination of physicochemical properties of the developed cutting fluid was carried out.

iii. Performance evaluation of the surface finish, chip thickness ratio and the amount of heat generated during machining process with the cutting fluid was carried out.

1.6 Justification

(i) The search for biodegradable cutting fluid to replace the mineral oil based cutting fluid was undertaken.

(ii) This study aims to ascertain the economic and technological viability of local oils as a useful substitute for present cutting fluids.

(iii) The need to produce environmentally biodegradable cutting fluid is high due to the fact that convectional cutting fluids have adverse effects on operators and environment. (Lopez de Lacalle *et al*., 2006).

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

One of the interesting recent developments is the growing realization that bioresources present practical alternatives to fuels and lubricants derived from liquid fossil fuels. However, no pure vegetable or mineral oil possesses all the properties required by modern technology in machining processes, therefore, a mixture of some sort is necessary. This has led to the development of several cutting fluids using many soluble mineral oils (Akpobi and Enabulele, 2002).

Cutting lubricants may consist of pure oil, a mixture of two or more oils or a mixture of oil and water (Akpobi and Enabulele, 2002). Oils are generally divided into two groups: the fixed oils and mineral oils. The fixed oils have greater "oiliness" than the mineral oils, but they are not so stable and tend to become gummy and decompose when heated. In this group are animal and vegetable oils. On the other hand, the mineral oils group is obtained from crude petroleum mined from oil fields. The most common type of lubricant used for cutting is soluble oil, which when mixed with water, forms a white solution known as "suds" or "slurry". This has better cooling properties than oil, (it is justified by the presence of water, which has the best cooling properties but poor in lubrication) but does not lubricate as well. The oil part of it is generally a mineral oil mixed with a soap solution (Chapman, 2002).

During machining operations, heat is generated and this has adverse effects on the work piece surface finish and dimensional accuracy, tool wear and life, as well as production rate.

Lubricants are therefore employed in machining operations to either achieve cooling, cooling and lubrication, or minimize chip adhesion to the work piece or tool; and the goal of employing a lubricant in any machining operation is dependent on choice lubricant functions. (Chernor, 1999 and Chapman, 2002).

Whichever functions a cutting fluid is to serve in any machining operation, it must possess some qualities, which have been identified as:

(i) High decomposition or oxidation temperature, not too sticky, should not foam or smoke unduly, must not be a contaminant to lubricants used elsewhere in the machine. If these qualities are lacking, the cutting fluid may result in serious ecological or health issues (Ibhadode, 2001).

(ii) It has been observed that expenses on cutting fluids form a major parts of manufacturing costs per part produced. It is therefore, a cost cutting measure to develop cost effective and efficient cutting fluids for machining processes. This could be achieved through the use of cheap and readily available vegetable oils (Ibhadode, 2001).

2.2 Cutting Fluid

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 (Ibhadode, 2001). 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.

2.2.1 Characteristics of a good Cutting fluid:

A good cutting fluid should have the following properties;

(i) Ability to keep the work piece at a stable temperature (critical when working to close tolerances).

(ii) Ability to maximize the life of the cutting tip by lubricating the working edge and reducing tip welding.

(iii) To ensure safety for the people handling it (toxicity, bacteria, and fungi) and for the environment on disposal.

(iv) To prevent rust on machine parts (Ibhadode, 2001).

2.3 Functions of Cutting fluid

The functions of cutting fluid are basically two; cooling and lubrication.

(i) Cooling: Metal cutting operations generate heat due to tool friction and energy used in deforming the material. The surrounding air is a poor coolant for the cutting tool because it conducts heat poorly and has low thermal mass. Ambient-air cooling is adequate for light cuts and low duty cycles typical of maintenance, repair and operations (MRO) or hobbyist work. However, production work requires heavy cutting over long periods and typically produces more heat than air cooling can remove. Rather than stopping production while the tool cools, using liquid coolant removes heat rapidly, and can also increase cutting rate and reduce friction and tool wear.

(ii) Lubrication: Besides cooling, cutting fluids also aid the cutting process by lubricating the interface between the tool's cutting edge and the chip. 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.

2.4 Types of Cutting fluids

Practically all cutting fluids presently in use fall into one of these four categories: (Ibhadode, 2001)

(i) Straight oils are non-emulsifiable and are used in machining operations in undiluted form. They are composed of a base mineral or petroleum oil and often contain polar

lubricants such as fats, vegetable oils and esters as well as extreme pressure additives such as chlorine, sulphur and phosphorus. Straight oils provide the best lubrication and the poorest cooling characteristics among cutting fluids (Ibhadode, 2001).

(ii) Synthetic fluids contain no petroleum or mineral oil base and instead are formulated from alkaline inorganic and organic compounds along with additives for corrosion inhibition. They are generally used in a diluted form (concentration ratio between 3 to 10%). Synthetic fluids often provide the best cooling performance among cutting fluids (Ibhadode, 2001).

(iii) Soluble oil fluids form an emulsion when mixed with water from table 2.1. The concentrate consists of a base mineral oil and emulsifiers to help produce a stable emulsion. They are used in a diluted form (usual concentration = 3 to 10%) and provide good lubrication and heat transfer performance. They are widely used in industry and are the least expensive among all cutting fluids (Ibhadode, 2001).

(iv) Semi-synthetic fluids are essentially combinations of synthetic and soluble oil fluids and have characteristics common to both types. The cost and heat transfer performance of semi-synthetic fluids lie between those of synthetic and soluble oil fluids (Ibhadode, 2001).

Table 2.1: Properties of conventional soluble oil (Source: ConocoPhillips Company, 2011)

Typical Properties	**Values**
Specific Gravity @ 60^0F	0.919
Density, Ibs/gal @60^0F	7.65
Color, ASTM D1500	3.5
Flash Point (PMCC), ^{0}C (^{0}F)	184 (363)
Pour Point, ^{0}C (^{0}F)	-43 (-45)
Viscosity,	
cSt @ 40^0C	34.2
cSt @ 100^0C	5.0
SUS @ 100^0F	178
SUS @ 210^0F	43.1
Viscosity index	51
Emulsion stability	Good
Iron Chip Corrosion Test, 5% dilution, ASTM D4627	Pass
pH, 5% (1:20) dilution	10.3
Rust Test, ASTM D 665 A & B	Pass
Chlorine, wt %	Nil
Fatty Oil, wt %	Nil
Sulfur, Total, wt %	0.43
Sulfur, Active, wt %	Nil

2.5 Classification of Cutting fluids

(i) Liquids: There are generally three types of liquids: mineral, semi-synthetic, and synthetic. Water is a great conductor of heat but has drawbacks as a cutting fluid. It boils easily and promotes rusting of machine parts. Therefore, other ingredients which are necessary to create an optimal cutting fluid need to be added (Ibhadode, 2001).

(ii) Pastes or Gels: Cutting fluids may also take the form of paste, or gels, which are used for some applications, in particular, hand operations such as drilling and tapping. In sawing metal with a band saw, it is common to periodically run a stick of paste against the blade. This product is similar in form to lipstick or beeswax. It comes in a cardboard tube, which gets slowly consumed after application.

(iii) Aerosols (Mists): Some cutting fluids are used in aerosol (mist) form (air with tiny droplets of liquid scattered throughout). The main problems with mists have been that they

are bad for the workers, who have to breathe the surrounding mist tainted air, and these substances often don't even work well. Both problems come from the imprecise delivery that often puts the mist everywhere all the time, except the cutting interface where it is needed. However, a newer form of aerosol delivery, MQL (minimum quantity of lubricant), avoids both of these problems (Ibhadode, 2001).

(iv) Air or other gases (e.g., nitrogen): Ambient air, of course, was the original machining coolant. Compressed air, supplied through pipes and hoses from an air compressor and discharged from a nozzle aimed at the tool, is sometimes a useful coolant. The force of the decompressing air stream blows chips away, and the decompression itself has a slight degree of cooling action (pV= nRT); lowering the pressure lowers the temperature) (Ibhadode, 2001).

2.6 Importance of Cutting fluids

The primary needs of cutting fluids(in machining) are as follows, lubricating the cutting process primarily at low cutting speeds**,** Cooling the work piece primarily at high cutting speeds and flushing chips away from the cutting zone. While, Secondary importance of cutting fluids includes, Corrosion protection of the machined surface and enabling part handling by cooling the hot surface (Ibhadode, 2001).

2.7 Additives for Lubricants

Additives are substances formulated for improvement of the anti-friction, chemical and physical properties of base oils (mineral, synthetic, vegetable or animal), which result in enhancing lubricant performance and extending equipment life. Combinations of different additives and their quantities are determined by the lubricant type (engine oils, gear oils, hydraulic oils, cutting fluids, way lubricants, compressor oils etc.) and the specific operating conditions (temperature, loads, machine parts materials, environment).The amount of additives may reach 30%. (Woods, 2005).

Additives include:

(i) Friction modifiers and Anti-wear additives

(ii) Extreme pressure (EP) additives

(iii) Rust and corrosion inhibitors

(iv) Anti-oxidants

(v) Detergents

(vi) Dispersants

(vii) Pour point depressants

(viii) Viscosity index improvers

(ix) Anti-foaming agents

2.7.1 Friction modifiers

Friction modifiers reduce the coefficient of friction, resulting in less fuel consumption. The crystal structure of most of friction modifiers consist of molecular platelets (layers), which easily slide over each other. The following Solid lubricants are used as friction modifiers: Graphite, Molybdenum, disulfide, Boron nitride (BN), Tungsten disulfide (WS_2) and Polytetrafluoroethylene (PTFE) (Woods, 2005).

2.7.2 Anti-wear additives

Anti-wear additives prevent direct metal-to-metal contact between the machine parts when the oil film is broken down. Use of anti-wear additives result in longer cutting tool life due to higher wear and score resistance of the components. The mechanism of anti-wear additives: the additive reacts with the metal on the part surface and forms a film, which may slide over the friction surface. The following materials are used as anti-wear additives: Zinc dithiophosphate (ZDP), Zinc dialkyldithiophosphate (ZDDP) and Tricresylphosphate (TCP) (Woods, 2005).

2.7.3 Extreme pressure (EP) additives

Extreme pressure (EP) additives prevent seizure conditions caused by direct metal-to-metal contact between the parts under high loads. The mechanism of EP additives is similar to that of anti-wear additives: the additive substance forms a coating on the part surface. This coating protects the part surface from direct contact with the other part, decreasing wear and scouring.

The following materials are used as extra pressure (EP) additives: Chlorinated paraffins,Sulphurizedfats,Esters, Zinc dialkyldithiophosphate (ZDDP) and Molybdenum disulfide (Woods, 2005).

2.7.4 Rust and Corrosion inhibitors

Rust and corrosion inhibitors form a barrier film on the substrate surface reducing the corrosion rate. The inhibitors are also absorbed on the metal surface forming a film protecting the part from the attack of oxygen, water and other chemically active substances. The following materials are used as rust and corrosion inhibitors: Alkaline compounds, Organic acids, Esters and Amino-acid derivatives (Woods, 2005).

2.7.5 Anti-oxidants

Mineral oils react with oxygen of the air forming organic acids. The oxidation reaction products cause increase of the oil viscosity, formation of sludge and varnish, corrosion of metallic parts and foaming. Anti-oxidants inhibit the oxidation process of oils. Most lubricants contain anti-oxidants. The following materials are used as anti-oxidants: Zinc dithiophosphate (ZDP) and Alkyl sulfides (Woods, 2005).

2.7.6 Detergents

Detergents neutralize strong acids present in lubricants (for example sulfuric and nitric acid produced in internal combustion engines as a result of the combustion process) and remove the neutralization products from the metal surface. Detergents also form a film on the part surface preventing high temperature deposition of sludge and varnish. Detergents are commonly added to engine oils. Phenolates, sulphonates and phosphonates of alkaline and alkaline-earth elements, such as calcium (Ca), magnesium (Mg), sodium (Na) or (Ba) barium, are used as detergents in lubricants (Woods, 2005).

2.7.7 Dispersants

Dispersants keep foreign particles present in a lubricant in a dispersed form (finely divided and uniformly dispersed throughout the oil). The foreign particles are sludge and varnish, dirt, products of oxidation, water etc. Long chain hydrocarbon succinimides, such as polyisobutylenesuccinimides are used as dispersants in lubricants (Woods, 2005)

2.7.8 Pour point depressants

The pour point is the lowest temperature, at which the oil may flow. Wax crystals formed in mineral oils at low temperatures reduce their fluidity. A pour point depressant inhibits formation and agglomeration of wax particles keeping the lubricant fluid at low temperatures. Co-polymers of polyalkylmethacrylates are used as pour point depressants in lubricants (Woods, 2005)

2.7.9 Anti-foaming agents

Agitation and aeration of a lubricating oil occurring at certain applications (engine oils, gear oils, compressor oils) may result in formation of air bubbles in the oil - foaming. Foaming not

only enhances oil oxidation but also decreases lubrication effect causing oil starvation. Dimethylsilicones (dimethylsiloxanes) is commonly used as anti-foaming agent in lubricants. (Woods, 2005).

2.7.10 Viscosity Index Improvers

Viscosity of oils sharply decreases at high temperatures. Low viscosity causes decrease of the oil lubrication ability. Viscosity index improvers keep the viscosity at acceptable levels, which provide stable oil film even at increased temperatures. Viscosity improvers are widely used in multigrade oils, viscosity of which is specified at both high and low temperatures. Acrylate polymers are used as viscosity index improvers in lubricants (Woods, 2005).

2.8 Selection of Cutting Fluids

The selection of a cutting fluid for a particular machining operation depends on two factors, the type of machining work to be done, and the material being machined. It is thus possible to draw up lists of recommendations in two different forms. One form based on the operation. The other based on the type of material being worked. The Table 2.2 provides a more valuable suggestion of cutting fluids for particular operations.

Table 2.2: Type of machining operation and its cutting fluid (Abioye and Bawonda, 2000)

s/n	Types of operation	Cutting fluid used
1	Automatic machines	Compounded oil or mineral oil or organic oil.
2	Boring	Emulsion(water+ mineral oil +soap)
3	Broaching	Compounded oil or mineral oil or emulsion
4	Drilling	Emulsion(water+ mineral oil + soft soap)
5	Milling	Emulsion(water+ mineral oil + soft soap)
6	Parting off	Compounded oil or emulsion
7	Planning	Dry
8	Tapping	Mineral oil or organic oil or emulsion.
9	Threading	Compounded or organic oil or white lead + oil+ sulphur
10	Turning	Emulsion(water+ mineral oil + soft soap)
11	Turret lathe work	Compounded oil or emulsion

From Table 2.3 it can be deduce that due to the presence of double bonds in unsaturated fatty acids, the addition of halogens such as Cl_2 and I_2 is done easily. Chlorine is an extreme pressure element which prevents seizure and welding between metal surfaces under conditions of extreme pressure and temperature. They are therefore good as extreme pressure base oils. Chlorine is also an antiseptic agent, which prevents odour and together with sodium increases the emulsion life of the base oil. (Ajala, 1981)

The Table 2.3 provides information on free acid content, iodine, phosphorus saponification and viscosity of some vegetable based oil.

Table 2.3: Free acid, Saponification, Iodine, Phosphorus values and the Viscosity of local oil (Ajala, 1981)

Vegetable oil	% free acid	Saponification value	Iodine value	% Phosphorus	Viscosity at 27^0C (cps)
Palm oil	6.99 -31.99	225.41-227.56	64.5	0.048	24.5
G/Nut oil	0.11-0.24	223.04-230.23	106.10	0.067	22.5
Palm kernel oil	4.63	286.95	18.67	0.065	19.1
Shear butter oil	0.60-.69	167-177.7	68.2-68.7	-	25.7
Golden soya oil	3.0	189-165	120-141	0105	-
Cotton seed oil	0.11-.32	221.39-22.56	111.15	-	-

Previous studies (Greenwood,1999) and (Ajala,1981) have shown that local oils investigated are mainly fatty acids with compositions as shown in Table 2.4. With the presence of the carboxylic group the saturated fatty acids in the oils help in maintaining a strong molecular adherence of the fatty oils to metal surfaces thereby minimizing friction.

Table 2.4: Chemical composition of local oils (Ojolo *et al*, 2008)

Fatty Acid	CHAIN LENGH	% of fatty acids in various oils					
		Palm Kernel	Cotton Seed Oil	Soya Beans Oil	Palm Oil	G/Nut Oil	Shear Butter Oil
Myristic	14.0	17.0	1.0	0.1- 0.4	1.7	-	-
Palmitic	16.0	8.0	48	7-11	42.3	7.5	5.7
Stearic	18.0	2.0	4	2.4-6	52.0	4.5	41
Caprytic	8.0	3.0	-	-	-	-	-
Capric	10.0	4.0	-	-	-	-	-
Lauric	12.0	51.0	-	-	-	-	-
Arachidic	2.0	-	-	-	-	3.0	-
Beharic	22.0	-	-	0.3-2.4	-	2.0	-
Lignoceric	24.0	-	-	-	-	2.0	-
Oleic	18.0	13.0	38	22-34	40.6	62.0	49.0
Linoleic	18.0	2.0	9	50-60	9.9	19.0	4.3

(Shaw, 2004) and (Bowden and Tabor, 2001) have observed that the longer the chain lengths of the fatty acid contents the more the area the fluid will protect from the rubbing effect of the

sliding chip- tool interface, hence an improved tool life. (From Table 2.4) Oleic and linoleic acids are also unsaturated fatty acids and so they are reactive (due to the presence of double bonds) in addition to the presence of carboxylic groups. They therefore, contribute to the formation of the absorbed layer by the local oils unto the metal surface.

The leading role shown by soya bean oil from Table 2.4 can be attributed to its possession of high percentage of oleic acid (22-34%) and linoleic (50-60%) acid with long chain lengths among the oils from Table 2.3. Soya bean oil also performs well perhaps due to its low viscosity, which enables it to penetrate deep despite the counter effects of chips.

(Arshinov and Alekseev, 2003) reported that the presence of surface active agents such as stearic acid and halogens such as chlorine helps to reduce the surface energy of a liquid and increase its wetting power or oiliness.

2.9 Soya bean as Vegetable based Oil

A soya bean (glycline max) is essentially a subtropical crop but it also grows wild and it is wide spread in tropical Africa and Asia. It is now one of the world's most important legumes and a major source of edible oil and vegetable protein. Soya beans occupies a premier position as a world crop because of its high and virtually unrivaled protein content and also because it is a rich source of edible vegetable oil. Spherical and yellow, though black, brown and green soybeans exist, they are about 8% hull, 90% cotyledon and 2% hypocotyls'. Although, a soya bean is a legume seed, with the possible exception of the winged beans, it is often classed as an oil- seed with oil content of 13-20%).

2.10 Cutting Fluid Formulation and Characterization

The general composition of cutting fluids can be characterized as an addition of base oil and emulsifier. Other components may be added to the fluid. such as: solution improvers,

neutralization agents, corrosion and rust inhibitors, lubricating additives, biocides and fungicides, agents to improve stability in hard waters and foam inhibitors.

2.11 Surface Roughness and Classification

Surface finish can be defined as the relative roughness of a surface or the deviation from the nominal surface. It can also be defined as the condition of a surface as a result of a final treatment. A nominal is a theoretical perfect surface envisaged by the machinist. These deviations take the form of surface irregularities such as (Sharma 2005).

a) Surface flaws

b) Waviness

c) Lay

d) Roughness

There are four causes of surface irregularities. These are as follows (Sharma 2005);

(i) Field marks or ridges left by the outline shape of the cutting tool,

(ii) Fragments of built-up edge shed on the work surface in the process of chip formation,

(iii) Vibration displacement between tool and work

(iv) Poor cutting conditions as a result of applying unsuitable coolant/lubricant to specified machining jobs.

The surface finish of machined parts is affected by numerous factors such as work material, type of chip formation, cutting speed, feed rate, depth of cut and type of cutting fluid used (Sharma 2005)

2.12 Methods of Evaluating Surface Roughness

Evaluation of roughness of a work piece can be done by the following methods; (Sharma 2005)

(i) Arithmetical mean deviation of profile (Ra) or center line average (CLA) and

(ii) Height of irregularities or maximum peak to valley height of roughness (H).

2.12.1 Center Line Average Method (CLA)

The C.L.A value is the standard adopted in Great Britain and U.S.A since 1955. It is defined as the average height from a mean line of all ordinates of the surface, regardless of the sign

This can be represented as,

$$\text{C.L.A.} = \left(\frac{h_1+h_2+h_{3+\cdots}h_n}{n}\right) \qquad (2.1)$$

Where, h_1, h_2, h_3 ... h_n (mm) are peak heights of surface roughness.

n = number of peaks of surface roughness.

To determine a C.L.A. value by the erection of ordinates would be a laborious process, and if an unfortunate ordinate spacing was chosen a significant point on the surface could be missed.

However, if an irregular area is divided by its length then the value obtained is the average height of the area. Such an area can be measured using a plan meter, thus considering an infinite number of ordinates, and every point on the surface is considered.

$$\text{C.L.A.} = \frac{A1+A2+A3+\cdots\ldots\ldots An}{L}, \qquad (2.2)$$

Where, A_0 = area of various peaks (mm^2)

L= line length (mm)

2.12.2 Peak to valley height

The name peak to valley height would indicate a relatively simple method of analysis, but if interpreted in its wider sense it means that the peak and valley used would almost certainly be exceptional and the value obtained would not give a representative assessment of the surface.

To overcome this, the P-V height is defined as the distance between a pair of lines running parallel to the general 'lay' of the trace positioned so that the length lying within the peaks at the top is 5% of the trace length, and that within the valley at the bottom is 10% of the trace length. (Sharma, 2005)

This can be represented mathematically as, (Sharma, 2005)

$$\text{p. v. a height} = \frac{(p_1+p_2+p_3+\ldots+p_n)-(v_1+v_2+v_3+\cdots+v_n)}{n} \qquad (2.3)$$

Where, $p_1, p_2, p_3 \ldots p_n$ various peak height in (mm)

$v_1, v_2, v_3 \ldots v_n$ various depths of valley in (mm)

2.13 Measurement of Surface finish

Several methods and instruments have been developed for the measurement of surface finish. These include the spectral method, interference method, comparison microscopes, optical reflectance, stylus tracer instruments, the Tomlinson recorders, Talysurf and the Abbott profilometers.

2.14 Effect of Cutting Speed on Surface finish

The main cause of surface roughness is fragments of built-up edge shed on the surface, in the process of chip formation. The built-up edge has been found to be favored by low cutting speeds (Chapman, 2002). Thus low cutting speeds will be expected to produce surfaces with high roughness values. Better finishes are obtained at high cutting speeds. Since at such speeds the condition for the built- up nose formation deteriorates, due to the rise in temperature the height of the built-up-edge is reduced, at certain high cutting speeds it disappears altogether. This leads to a corresponding reduction in surface roughness.

Upon further increase in cutting speed, the surface roughness continues to decrease due to reduction in friction between the tool flank and the machined surface.

The surface finish in machining operations depends on the type of chip formed and work material. Discontinuous chip formation can cause cracks to extend into the finished work surface and create force fluctuations which deflect the tool, forming ridges on the machined surface. However, at high speeds good crack-free surfaces can be obtained. When cutting fluids and increased cutting speeds are used, the built-up edge is eliminated and the chip formation can be changed from discontinuous to continuous. Friction and forces on tool rake face are usually reduced when increased cutting speeds are used. An increase in cutting speed also causes an increase in the shear plane angle which gives better finishes

2.15 Effect of Depth of Cut and Feed Rate on Surface Finish

Generally, the effect of depth of cut on surface finish is lower when compared to that of feed rate. An increase in the depth of cut increases the surface roughness due to the plowing effect of the cutting tool. (Chapman, 2002). Cutting forces are increased when depth of cut is

increased in a cutting operation, feed marks left by the tool profile become more pronounced though lower forces are generated.

Friction exists between the sliding chip and the tool face, work piece and the worm flank of the tool. A reduction in friction at such surfaces, not only decreases tool forces but also improves surface finish. Dry machining (machining without coolant) produces asperous surfaces, high friction and increased temperature, causing partial melting of the immediate areas in the tool-work piece interface. A phenomenon known as "seizure" is therefore brought into play. Seizure is a condition where particles from the work surface tend to detach from the work face and adhere to the tool surface, which can cause built- up-edge. The melted film between tool and work piece interface brings about "welding", which may cause deterioration of work piece surface and superficial burn of work surface and tool. A weakened tool will increase surface roughness.

The presence of cutting fluid will not only protect the tool and work piece surface from the plucking out of particles from adjacent metal interface, but cause among others anti-welding or resistance to surface adhesion and galling. Surface protection is achieved by film absorption. When cutting fluids are used in any metal cutting operation, there is always a penetration of an oil layer of molecules on the work piece and tool surface, when oil molecules are set against the tool work piece surface; they form a primary layer of oil molecules which adhere strongly to two surfaces.

These layers of oriented molecules are located on a very slight thickness on the surface. This primary layer acts more as a lubricant than as a coolant and provides the protection having very low shear strength.

A general observation is that wet machining operations produce smoother surfaces than dry machining. Cooling prevents excessive work piece expansion due to heat of deformation and

or frictional heat. Dimensional stability of the work piece is greatly enhanced with the use of efficient cutting fluids.

Fatty oils have a special property which enables them to move towards the hotter part of a flat metal part. This feature is due to a more rapid lowering of surface tension within the fatty oil. This improves the penetrating and spreading property. It quickens the formation of an adsorbed film on the surface, thereby reducing friction by raising the load carrying ability of the oil film. This property is advantageous in metal cutting operations even with dull tool usage.

Thus the frictional force in the flank region and dimensional in-accuracy can be properly remedied to give high surface quality.

2.16 Machining Processes

There are various techniques of metal cutting which include: drilling, turning, milling, shaping, planning, broaching, grinding and ultrasonic machining.

(i) Drilling: This is performed with a rotating tool called a drill, which is usually referred to as twist- drill. The basic machine used for drilling is called the drill press, an operation such as reaming, which consists of removing a small amount of metal from hole already drilled and tapping, the process of cutting a thread inside a hole so that a cap screw or bolt may be threaded into it, are classified as drilling (Ibahadode, 2001).

(ii) Milling: Milling removes metal with a revolving, multiple cutting edge tools called a milling cutter. Milling can produce flat or angled surfaces, grooves, slots, gear teeth and other profile, depending on the shape or the cutters being used. The basic machine being used for milling operations is called milling machine. Milling cutters are also used on jig boring machine, engraving machines and many specialized production machine (Ibahadode, 2001).

(iii) Shaping and Planning: Shaping and planning produce flat surfaces with a single- point cutting tool. In shaping, the cutting tool on a shaper reciprocates while the work is fed automatically towards the tool. A small amount of material is removed with each stroke. The shaper is commonly used for machining short, flat surface and for making grooves and key ways the surface may be horizontal, vertical, angular or irregular (Ibahadode, 2001).

In planning, the work piece is attached to a worktable that reciprocates past the cutting tool. The cutting tool is automatically fed into the work piece a small amount on each stoke, the planner is used for machining large flat surfaces and long grooves, it can also machine horizontal, vertical, angular and irregular surfaces too (Ibahadode, 2001).

(iv) Broaching: This performs many of the operations once done by shaping. Broaching is more efficient, however, since it uses a multiple- tooth- cutting toll, which normally completes its cutting operations in one stroke. The teeth of the broaching tool are equally spaced and are positioned so that the tool advances into the work piece; each tooth removes a pre-determined amount of metal. (Ibahadode, 2001).

(v) Ultrasonic machining (USM): Ultrasonic machining, also called impact grinding, bombards the work piece with abrasive particles. The tool is made to vibrate a few hundredths of a millimeter at an ultrasonic frequency of about 20, 000 Hz. Fine abrasive particles suspended in a fluid, normally water, are circulated between the tool and work piece. The pumping action of the tool causes the abrasive particles to strike the work piece with high velocity, thus grinding the work piece to the shape of the tool. The advantage of USM is that it can be used to cut materials that do not conduct electricity, such as plastic, graphite, glass, ceramics etc. (Ibahadode, 2001).

(vi) Boring: Boring operations are performed to enlarge, finish and accurately locate holes. A hole is bored by means of a single-point cutting tool which travels along inside the work (Ibahadode, 2001).

(vii) Turning: The basic machine used for turning is the metal working lathe; the lathe is commonly called the father of the entire machine tool family and the only machine capable of producing itself. For turning operating, the lathe uses a single – point cutting tool which removes metals as it travels past the revolving work piece. The process is basically one of the surface generations and thus, true cylindrical, conical, and spherical or planer surfaces with coincident axes are reproduced in the work piece, depending on the direction of cutter travel (Ibahadode, 2001).

2.17 Force Effects

Measurements of forces during modern processing techniques are carried out from different points of view and hence different techniques are used. Generally the interest is either in process control or for process improvement. On this basis, the study of work- tool interaction forces is of great importance and practical interest in the entire chip forming operation.

2.17.1 Forces involved in Machining Processes

During the machining process the resultant force acts on the tool and it distributes itself along the chip-tool interface and is then distributed through the chip to the shear line, where yielding occurs. The actual force distribution along this surface may be resolved into normal and tangential components which are related by the coefficient of friction (Chapman 2002). The stress component along the shear line is K, while that perpendicular to this line is R. These are the only surfaces on which forces are acting, and for equilibrium of the chip, the forces must be equal to each other.

2.17.2 Determination of Shear Plane Angle

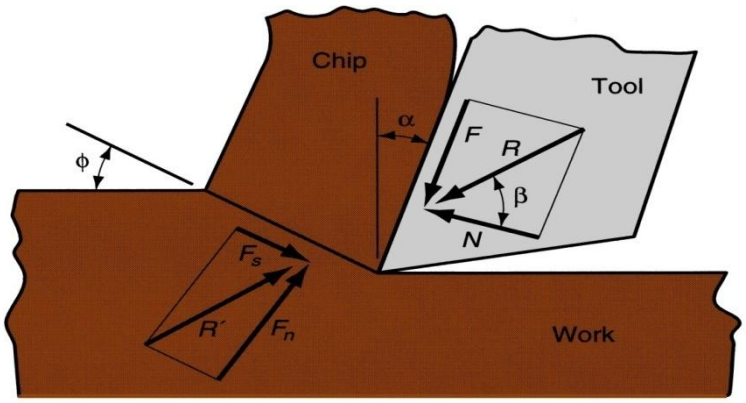


Figure 2.1 Forces in metal cutting: (a) forces acting on the chip in orthogonal cutting (Ramesh, 2000).

Based on the geometric parameters of the orthogonal model in figure 2.1, the shear plane angle ϕ can be determined as: (Ramesh, 2000)

$$tan\,\emptyset = \frac{rcos\alpha}{1-rsin\alpha} \qquad (2.4)$$

Where r = chip ratio, and α= rake angle.

2.17.3 Determination of Shear Strain

Shear strain in machining can be computed from the following equation. (Sharma, 2005)

$$\gamma = \tan(\phi-\alpha) + \cot\phi) \qquad (2.5)$$

Where, γ = shear strain, ϕ = shear plane angle, and α = rake angle of cutting tool.

2.17.4 Forces acting on Chip

(i) Friction force F and Normal force to friction N

(ii) Shear force F_s and Normal force to shear F_n

2.17.5 Coefficient of Friction

Coefficient of friction between tool and chip: the ratio of force to normal reaction. Given by: (Sharma, 2005)

$$\mu = \frac{F}{N}$$

(2.6)

Friction angle is related to coefficient of friction as follows: (Sharma, 2005)

$$\mu = \tan \beta$$

`

(2.7)

2.17.6 Shear Stress

Shear stress acting along the shear plane: (Sharma, 2005)

$$S = \frac{F_s}{A_s}$$

(2.8)

Where A_s = area of the shear plane.

$$A_s = \frac{t_o w}{\sin \phi}$$

(2.9)

Shear stress = shear strength of work material during cutting.

w = width of the chips

2.17.7 Forces in Metal Cutting

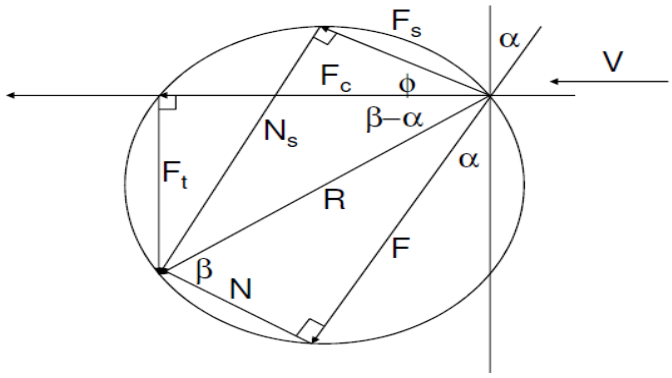


Figure 2.2: Merchant's Force Circle (Ramesh, 2000)

Equations can be derived to relate the forces from figure 2.2 that cannot be measured to the forces that can be measured: (Ramesh, 2000)

$F = F_c \sin\alpha + F_t\cos\alpha$ (2.10)

$N = F_c\cos\alpha - F_t \sin\alpha$ (2.11)

$F_s = F_c\cos\phi - F_t \sin\phi$ (2.12)

$F_n = F_c \sin\phi + F_t\cos\phi$ (2.13)

Where, $F_{C=}$ cutting force, $F_{t=}$ thrust force, $F_{t=}$ normal force

Based on these calculated forces, shear stress and coefficient of friction can be determined

2.17.8 Merchant's Shear Angle Relationship

Merchant's theory: shear angle φ assumes a value that minimizes the work done (or cutting force) in metal cutting. Assuming that β is independent of φ and shear yield stress of the work material is constant, Ø is given from Figure 2.2, by

$$\emptyset = 45 + \frac{\alpha}{2} - \frac{\beta}{2} \quad (2.14)$$

To increase shear plane angle; the parameters below can be varies.

(i) Increase the rake angle

(ii) Reduce the friction angle (or coefficient of friction)

(iii) Higher shear plane angle means smaller shear plane which means lower shear force

2.18 Cutting Temperature

Approximately 98% of the energy in machining is converted into heat, this can cause temperatures to be very high at the tool-chip and the remaining energy (about 2%) is retained as elastic energy in the chip. (Ramesh, 2000)

There are several analytical methods to calculate cutting temperature which are:

(i) The method by Cook (derived from dimensional analysis using experimental data for various work materials gives (Ramesh, 2000);

$$T = \frac{0.4U}{\rho c}\left[\frac{vt_0}{K}\right]^{0.333} \quad (2.15)$$

Where T = temperature rise at tool-chip interface; U = specific energy; v = cutting speed; t_o = chip thickness before cut; ρc = volumetric specific heat of work material; K = thermal diffusivity of the work material.

(ii) Experimental methods can be used to measure temperatures in machining. The most frequently used technique is the tool-chip thermocouple. Using this method, Trigger determined the speed- temperature relationship to be of the form: (Ramesh, 2000).

$$T = K v^{m}$$

(2.16) Where T = measured tool-chip interface temperature (Ramesh, 2000)

2.18.1 Chip Thickness Ratio

The ratio is given by; (Ramesh, 2000)

$$r = \frac{t_o}{t_c} \qquad (2.17)$$

Where r = chip thickness ratio; t_o = thickness of the chip prior to chip formation; and t_c = chip thickness after separation. Chip thickness after cut is always greater than before, so chip ratio is always less than 1.0

2.19 The Effects of Properties of Cutting fluids during Machining Operation.

Owing to high pressure and low speeds in most metal forming operations lubrication is of the boundary lubricants, such as fatty oils, fatty acids, soaps and waxes. The molecules of polar substances in boundary lubricants have long carbon chains with one or more chemically active groups at one end called polar groups. The polar groups adhere strongly to the work metal and tool causing the long carbon chains to be oriented approximately at right angles to the metal surfaces. These oriented films of polar substances (sometimes called oiliness agents) usually minimize friction and metal to metal contact.

Due to continued use, cutting tools fail to perform satisfactorily as a result of physical loss of the cutting edge (wear) which leads to loss of dimensional accuracy, excessive surface roughness and increased power requirements (Oxford, 2001)

In the cutting of metals, work is done in the plastic deformation of the layer being cut at the primary shear plane, in overcoming friction on the tool- chip interface called the secondary shear plane and the layer adjoining the machined surface and the tool flank or the tertiary shear plane (Smith, 1993).

The heat generated passes into the tool and reduces its hardness and makes it less wear-resistant. The use of cutting fluid ameliorates these adverse effects with the best fluid producing the best result. When lubricants are used, chips are thinner, meaning that a better lubricant should give a higher reduction of chip compression (Oxford, 2001), and reduction of chip thickness with speed and feed is an indication of reduction of cutting force, power consumed and temperature and that these depend on the cutting fluids used (Schmidt, 1999).

Fatty acids form salts (soaps) with metal ions because of the presence of terminal carboxyl groups. Their function may be one of effecting a dispersion of particulate matter and new trailing acids as well as acting as rust inhibitors (Oxford, 2001).

Cutting fluids promote the reduction in heat evolution (by facilitating chip formation and reducing friction), and also absorb and carry away part of the generated heat, thereby lowering the temperature (Arshinov and Alekseev, 2003).

2.20 Review of Past Works

Paul and Pal, (2011): investigated the performance of different types of cutting fluids (Karanja oil, neem oil, conventional fluid) as compared to dry cutting condition during turning of mild steel. The use of vegetable based cutting fluid improved surface quality as compared to dry turning and conventional cutting fluid. They explained the reason for the

lower temperature of neem vegetable oil and that of karanja vegetable oil and also, the lower viscosity of neem oil to that of karanja oil.

Xavior and Adithan, (2010): investigated the performance of coconut oil during machining of AISI 304 stainless and measured tool wear and surface roughness. The performance of coconut oil was compared with an emulsion and soluble cutting oil. They found that coconut oil reduced the tool wear and improved the surface finish.

Ojolo *et al*, (2008): used vegetable based cutting fluids (groundnut oil, coconut oil, palm kernel oil and shear butter oil) during turning of mild steel, aluminum and copper and measured cutting force. Although, it was found that the effects of vegetable based cutting fluids were material dependent, groundnut oil showed the best performance among the four vegetables based cutting fluid investigated.

Greenwood, (1999): carried out analysis of the local vegetable based oils such as tallow and rape oil and the verification of percentage of fatty acids was carried out and the presence of palmitic, stearic, oleic and linoleic acids was confirmed in reasonable quantities.

Obi *et* al, (2000): studied the effects of vegetable- based oils on cutting parameters in turning operations. The force and apparent coefficient of friction effects of three vegetable-based oils, groundnut, cottonseed oil and palm oil were assessed from values obtained from cutting dynamics by considering the cutting parameters of rake angle, depth of cut and chip thickness in the orthogonal cutting of mild steel, at various cutting speeds and feed rates. The results showed that the vegetable- based oils have better lubrication potentialities than the soluble oil normally employed in most machining operations based on their ability to reduce chip compression, apparent coefficient of friction and cutting force.

De Chiffre *et al*, (2001): investigated the effect of vegetable based cutting oil on cutting forces and power of an AISI 316L stainless steel work pieces were machined by drilling, core

drilling, reaming and tapping using HSS-E tools. Performance results obtained showed that vegetable based cutting oils were better than the commercial mineral oil.

Adithan *et al*, (2009): studied performance of coconut oil during the machining of AISI 304 material with a carbide tool. They found that coconut oil reduced the tool wear and improved the surface finish with respect to mineral oil.

CHAPTER THREE

3.0 MATERIALS AND METHOD

3.1 Materials

The materials for the experiment includes; soya beans, soluble oil, phenol, washing soda, sulphur, potassium hydroxide and acetone

3.2 Equipment

The equipment for the research includes; lathe machine, hydraulic press, pH meter, viscometer, infra –red- thermometer, beaker, conical flask and surface finish comparism tablet

3.3 Method of Developing Cutting fluid

The oil sample used in this work was prepared into cutting fluid using the suggestions given by earlier researchers in this field (Ibahadode, 2001 and Chapman, 2002). In preparing the sample of cutting fluid, 500 ml of vegetable oil was measured (using a 1-litre measuring beaker) and mixed with water in oil to water ratio of 1: 10 (Chapman, 2002). This mixture was thereafter blended with 10% vol/vol washing soap, 5% vol/vol phenol, 5% vol/vol sulphur, all at room temperature. See Table 3.1 for the function of some of the material.

Table 3.1 Cutting fluid formula

Material	Function	Content (% vol. /vol.)
Vegetable oil (soya beans)	Base oil	80
Washing soap	Emulsifier	10
Phenol	Disinfectant	5
Sulphur	Extreme pressure agent	5

3.4 Methods of Extracting Soya bean Oil

There are three methods that can be used for the extraction of soya bean oil; Hydraulic press; screw press and solvent extraction.

(i) Hydraulic Presses: for the hydraulic press, the soya beans were ground or flaked, steamed and tempered in a cooker, then formed into cake in press cloths and pressed at 500 – 4,000 psi to get the oil out (Bartlett et al., 1980).

(ii) Screw presses: In screw press, soya beans are fed into the machine so that a continuously revolving worm shaft forces then through a strong metal barrel or cage, whose walls are perforated with many thin slots, each about 0.01 inch (0.2 – 0.3 mm) wide. Under pressure of 5 – 10 tons or more per inch and temperatures for friction and pressure reaching 150 ^{0}C, the oil is pressed out (Bartlett et al., 1980).

(iii) Solvent extractors: The extraction process consists of "washing" the oil from the soya bean flakes with hexane solvent in a countercurrent extraction. Then the solvent is evaporated (i.e., desolventized) from both the solvent/ oil mixture (micella) and the solvent/oil mixture to steam. Then the solvent is condensed, separated from the steam condensate, and reused. Residual hexane not condensed is removed with mineral oil scrubbers, the desolventized oil, called "crude" soya bean oil, is stored for further processing or load out (Bartlett et al., 1980).

The screw press is simple but is relatively efficient and is suited to the conditions found in Africa. In this research, the screw press was used

3.5 Measurement of Surface finishing

For this project the surface feeling comparison apparatus was used to compare the various surfaces of the work piece and the standard surfaces because of its availability. The surface is compared visually and by a feel with standard. Comparison by feel is accomplished by running the edge of the finger nail or the tip of the finger over the work and specimen to

estimate and compare their roughness with graded standard which are copies of master surface finished by shaping, grinding, turning and milling etc. (Sharma, 2010).

3.6 Quality of Cutting Fluid:

3.6.1 pH

The cutting fluid's pH was determined by a digital pH meter.

3. 6.2 Determination of Acidic Value

Acid value indicates the proportion of free fatty acid present in oil or fat and may be defined as the number of milligrams of caustic potash required to neutralize the acid in 1gm of the sample. **The Experimental procedure:**

(i) 10 g of oil was weigh and transfer it into 250 ml conical flask.

(ii) 50 ml of neutralized alcohol solution was added to the oil solution.

(iii) This mixture was heated for 10 minutes by using heater.

(iv) The solution was taken after 10 minutes and 2 drops of phenolphthalein indicator was added.

(v) The solution was titrated against the KOH solution from the burette.

(vi) The appearance of pink colour indicates the endpoint

The number of milliliters of standard alkaline (KOH) required to dilute the sample was noted and the acid value of the fat (samples) was calculated at this point

3.6.3 Viscosity

A ball viscometer was used to determine the viscosity of the cutting fluid. The method of operation of the DV-E Viscometer was to rotate the spindle which was immersed in the test fluid through a calibrated spring. The viscous drag of the fluid against the spindle was measured by the spring deflection. Spring deflection was measured with a rotary transducer which provides a torque signal. The measurement range of a DV-E (in centipoises or Millipascal seconds) was determined by the rotational speed of the spindle, the size and shape

of the spindle, the container in which the spindle is rotating, and the full scale torque of the calibrated spring.

3.6.4 Corrosion

This test consists of corrosion grade of cutting fluid by its contact with mild steel. 5 grams of mild steel chips, were washed in acetone and dried, placed on a piece of filter paper in a Petri dish. The chips were evenly spaced around the filter paper, prevented from contacting one another and humidified in 2 ml of the test cutting fluid. The chips were then left in the covered Petri dish for 2 hours. At the end of 2 hours, the mild steel chip was discarded and the filter paper was rinsed in acetone. The corrosion grade of the cutting fluid was measured by observing how many spots appear on the filter paper surface and Table 3.1 was used for the analysis.

Table 3.2 Identification of corrosion grade (Ramesh, 2000)

Corrosion Grade	Mean	Filter paper surface
0	Without corrosion	No spots
1	Vestiges of corrosion	Three spots in the maximum
2	Low corrosion	Less 1% paper area with spots
3	Moderate corrosion	Between 1 and 5% paper area with spots.
4	High corrosion	More 5% paper area with spots

3.7 Performance and Evaluation of Cutting Fluids

The turning operation was performed in the mechanical engineering laboratory of Ahmadu Bello University, Zaria on the centre lathe with speeds 125, 180, 250, 355 and 500 rpm (see plate 3.3). The speeds in millimeter per revolution were varied and depth of cut in mm and feed rates in mm/rev were kept constant. While one of the quantities (speed, feed rate, depth of cut) was selected and varied, the other two were kept constant and chips produced were collected. The thickness of the chips produced was measured using a micrometer screw gauge and the corresponding thickness ratio was calculated.

During the turning operation the temperature of the cutting tool was measured using infra-red gun thermometer (see plate 3.2). It is important that the point of application of the fluid be chosen carefully and that the rate of flow is sufficient and uniform throughout the experimental procedure. (Ramesh, 2000)

3.7.1 Experimental Procedure

A mild steel rod of 12 mm diameter was machined on a lathe, using the developed cutting fluid and the convectional soluble fluid for performance evaluation (See plate 3.3). The work piece was faced and centered on the lathe before the test procedure started. The oils were used at room temperature.

Three different test- procedures were employed. First, the speed (rpm) was varied while the feed was kept constant at 0.5 mm/rev and the depth of cut at 0.2 mm. During this phase the cutting fluids were applied directly on the work piece tool interface using a small container. While the temperature variations were measured using an infra- red gun thermometer (see plate 3.2). In the second phase, the speed was kept constant at 180 rpm and the depth of cut at 1.2 mm while the feed was varied from 0.1 mm/rev to 0.5 mm/rev in five steps. Lastly, the speed and the feed were constant at 180 rpm and 0.5 mm/rev respectively, while the depth of cut was varied between 0.4 mm and 1.0 mm in steps of 0.5 mm. At the end of the three 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 (μmm) (see plate 3.1).

The value obtained from the chip thickness was used to calculate the ratio of the chip contraction which was recorded alongside the surface finish, temperature and other parameters.

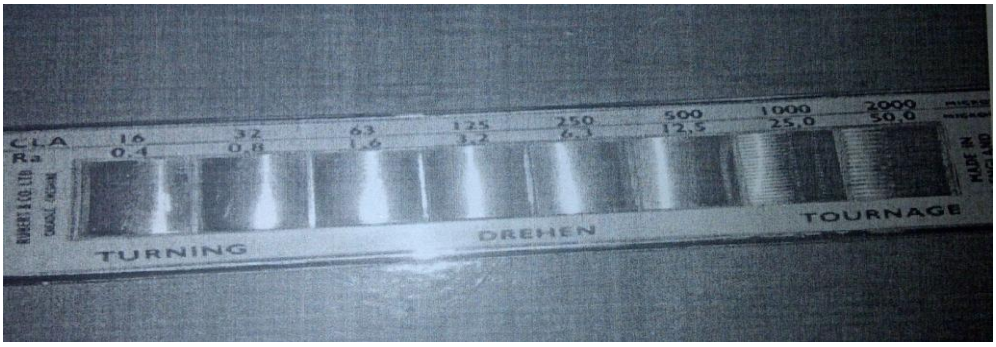


Plate 3.1: surface finish comparison tablet

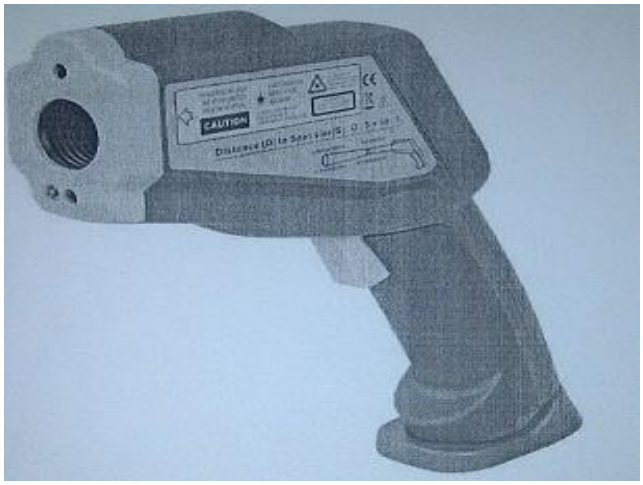


Plate 3.2: Infra-Red Gun Thermometer

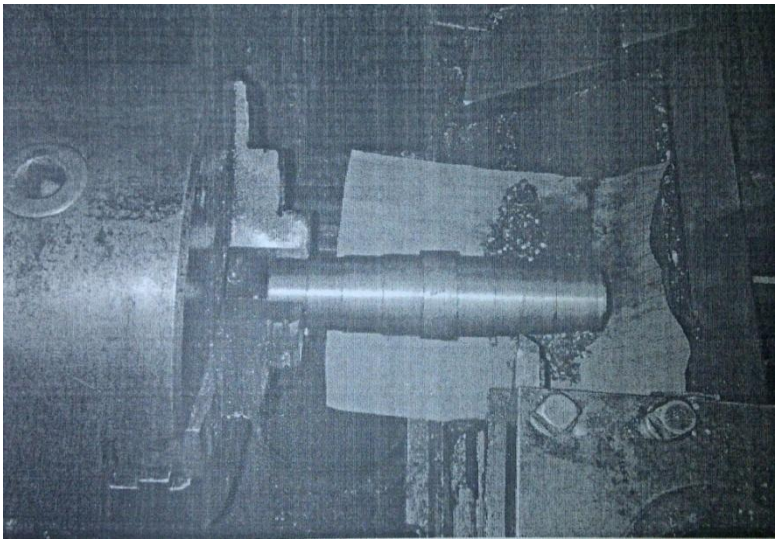


Plate 3.3: Turning operation on mild steel

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Results

The tables below show the results obtained in the machining of mild steel using conventional soluble oil and the developed oil for acidity, pH measurement, corrosion, viscosity and mechanical properties

4.1 Acidic values

Table 4.1: Acidic values of the lubricants

S/No	Sample	Acidic Value
1	Conventional cutting fluid	4.57
2	Developed cutting fluid	3.85

(See appendix for acid value calculation)

4.2 pH measurement

The pH values of the cutting fluids were measured with pH meter JENWAY 3510 and are shown in Table 4.2.

Table 4.2: values of pH measurement

s/no	sample	pH
1	Control sample	10.1
2	Developed soluble oil	8.03

4.3 Corrosion Measurements

The filter paper was washed with acetone. The metal chips were evenly separated on the filter paper then humidified with the cutting fluid solution.



(a) **(b)**

Plate 4.1: shows the corrosion measurement of conventional cutting fluid (a) and developed cutting fluid (b)

4.4 Measurement of Viscosity

Readings 31.4, 31.2, 31.3

Average Viscosity $\frac{(31.2 + 31.3 + 31.4)}{3} = 31.3$ cps

The viscosity of the lubricant is $0.0313 Ns/m^2$

Table: 4.3: Effect of cutting speed and lubricants in the machining of mild steel at constant feed of 0.5 mm/rev and constant depth of 2 mm

Cutting fluids	Speed (rpm)	Chip thickness (mm)	Chip thickness ratio	Surface finish (mm)	Temperature (^{0}C)
Conventional cutting fluid	90	0.214	0.107	2.76	52.1
	125	0.241	0.121	2.30	56.1
	180	0.326	0.163	2.30	58.3
	250	0.211	0.106	3.10	60.1
	355	0.534	0.267	1.50	70.0
Developed cutting fluid	90	0.318	0.159	2.30	51.0
	125	0.474	0.237	3.10	54.1
	180	0.521	0.261	2.76	62.3
	250	0.661	0.331	2.50	65.1
	355	0.541	0.271	2.30	67.5

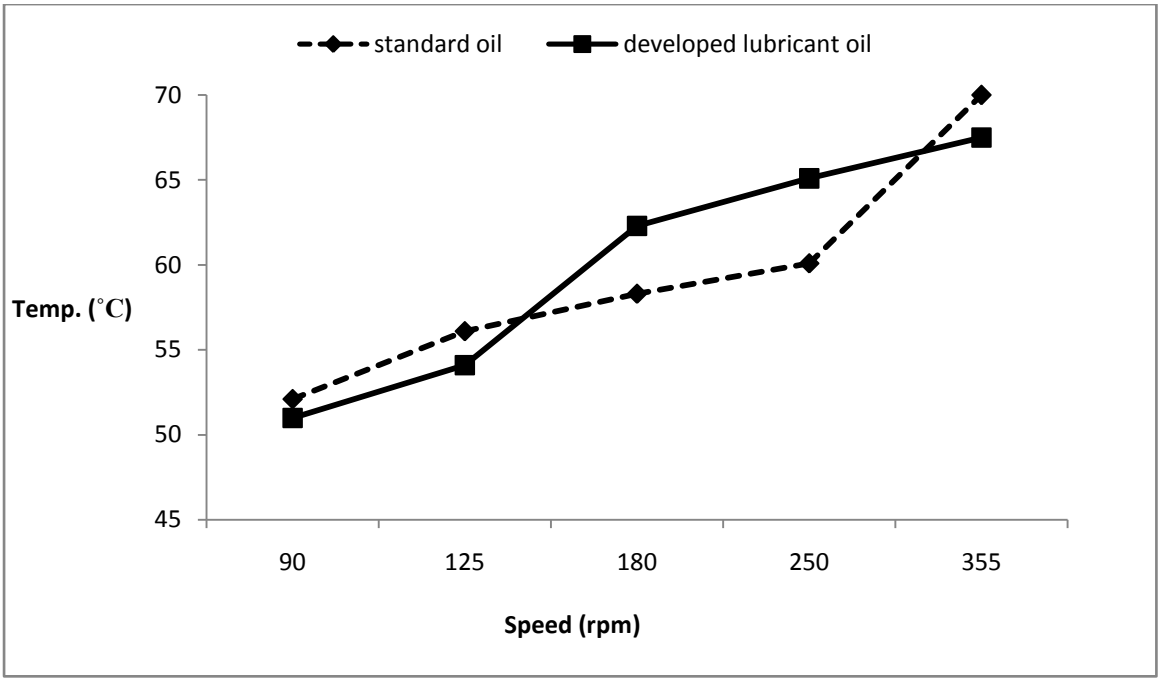


Figure 4.1 Variation of temperature with speed

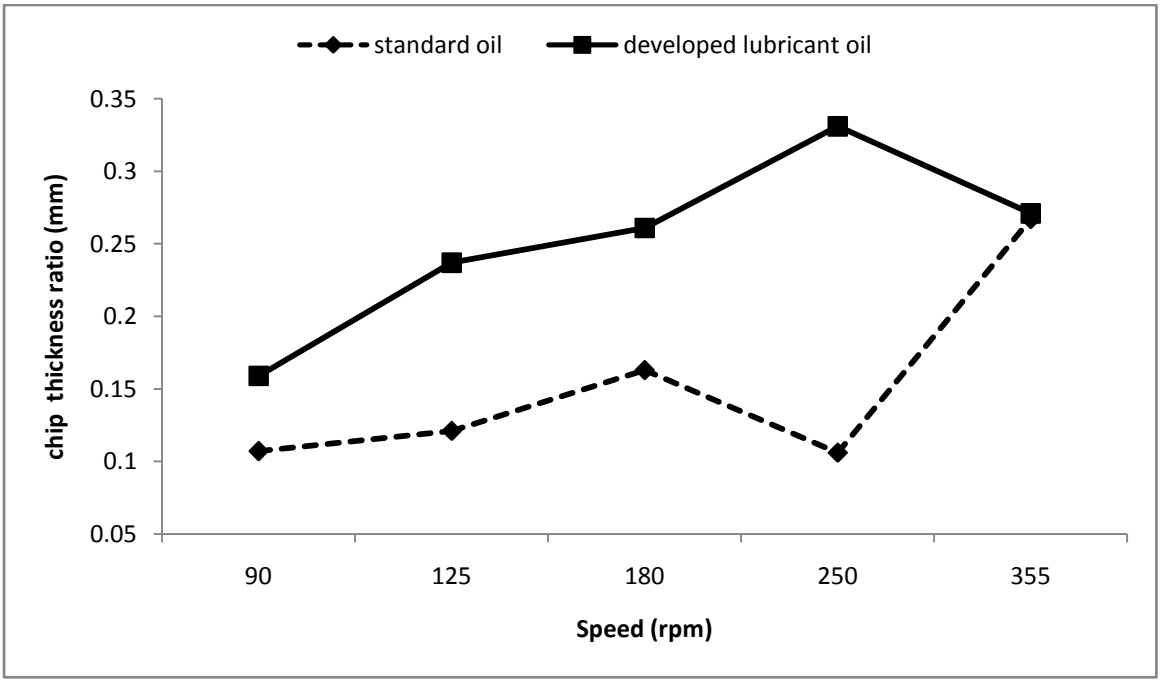


Figure 4.2 Variation of chip thickness ratio with speed

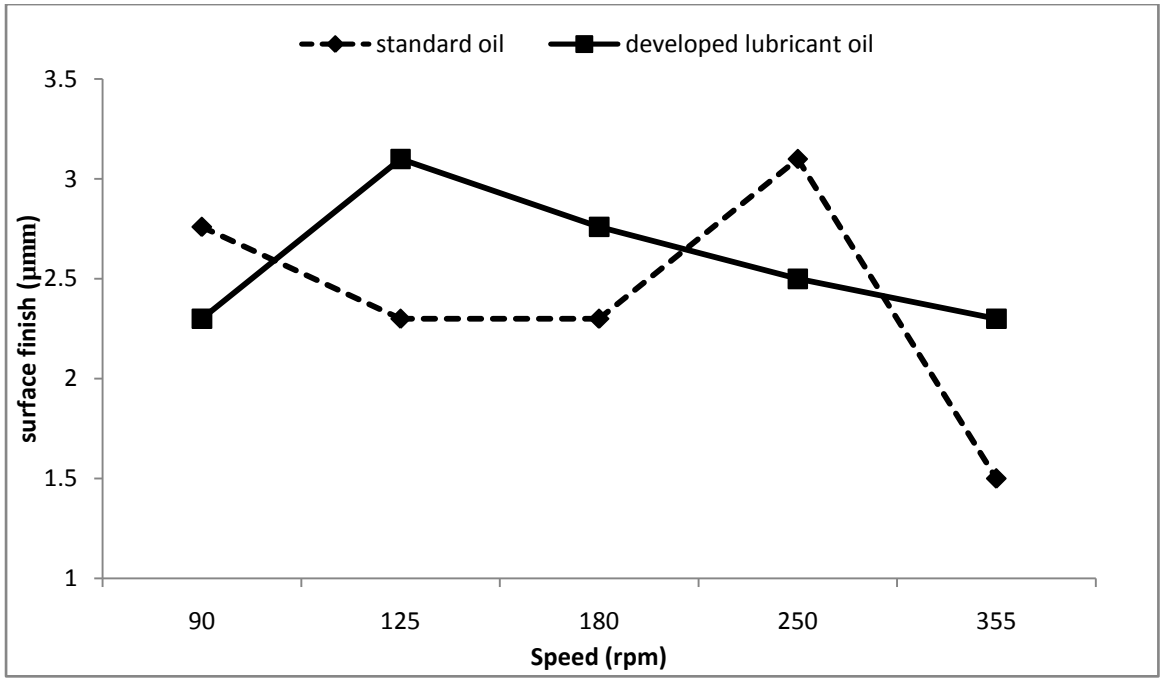


Figure 4.3 Variation of surface finish with speed

Table 4.4: Effect of lubricants on machining of mild steel when feed is varied at constant depth of 2 mm and speed of 180 rpm

Cutting fluids	Feed (mm/rev)	Chip thickness (mm)	Chip thickness ratio	Surface finish (mm)	Temperature (^{0}C)
Conventional cutting fluid	0.1	0.314	0.157	1.70	51.1
	0.2	0.152	0.100	1.65	54.1
	0.3	0.309	0.155	2.30	57.3
	0.4	0.212	0.106	3.00	59.1
	0.5	0.535	0.267	3.20	69.0
Developed cutting fluid	0.1	0.461	0.231	2.42	50.0
	0.2	0.334	0.167	2.20	53.1
	0.3	0.314	0.157	2.40	61.3
	0.4	0.281	0.141	2.80	64.1
	0.5	0.635	0.318	3.30	61.5

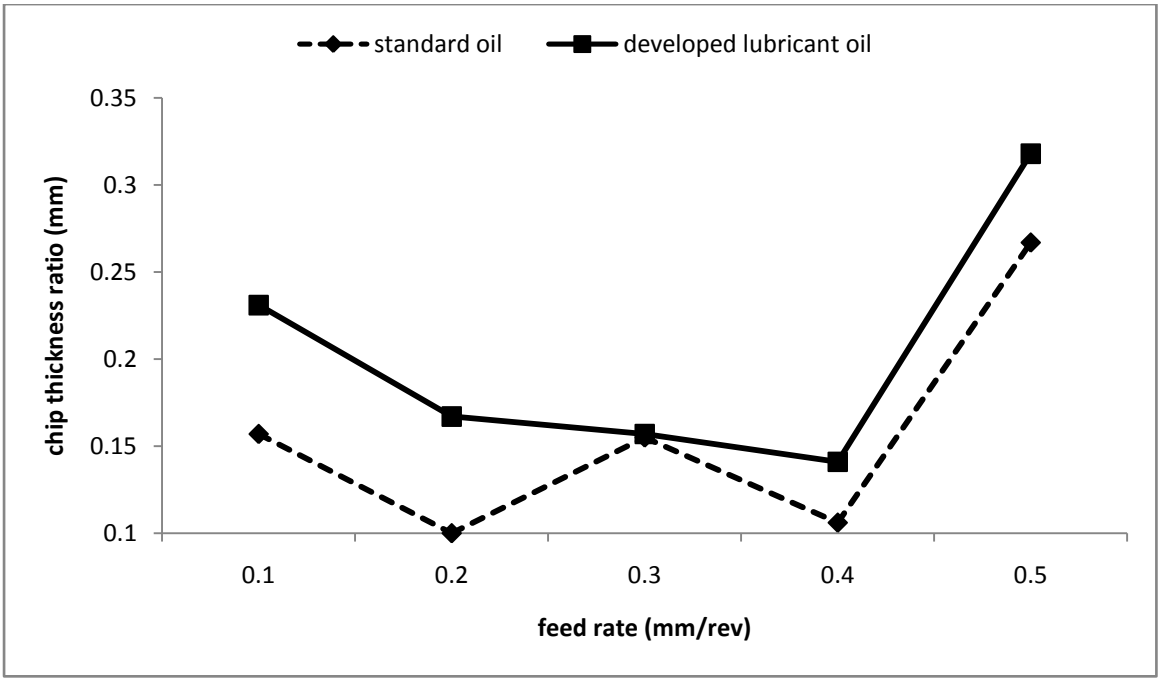


Figure 4.4 Variation of chip thickness ratio with feed rate.

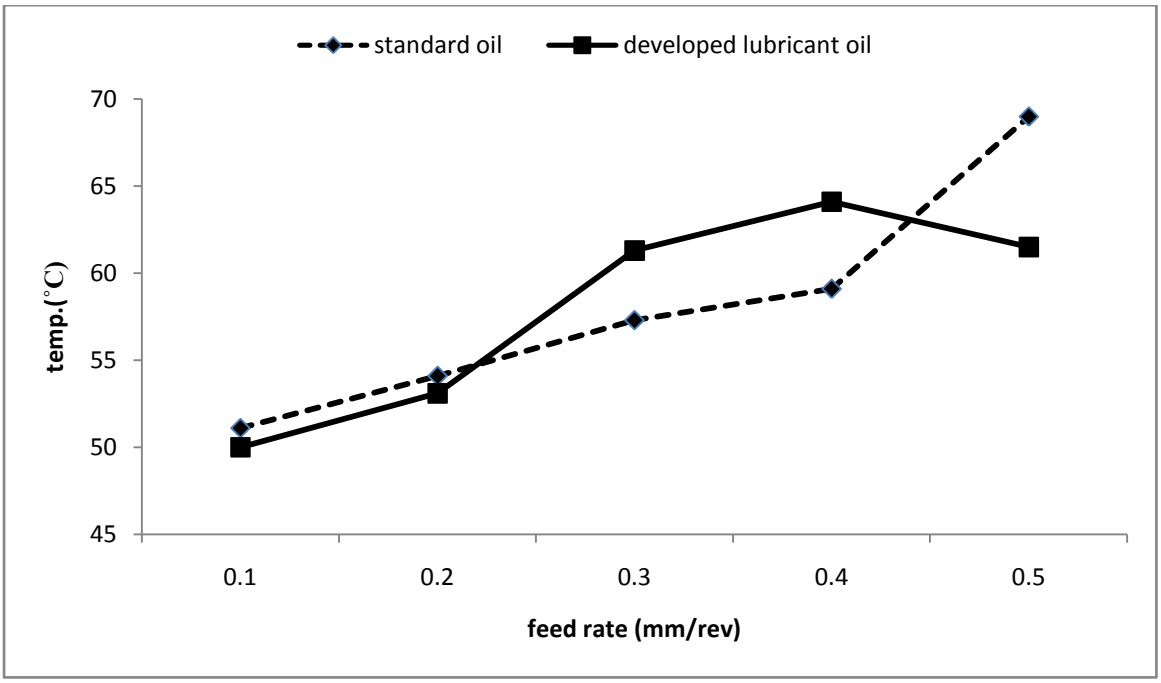


Figure 4.5 Variation of temperature with feed rate.

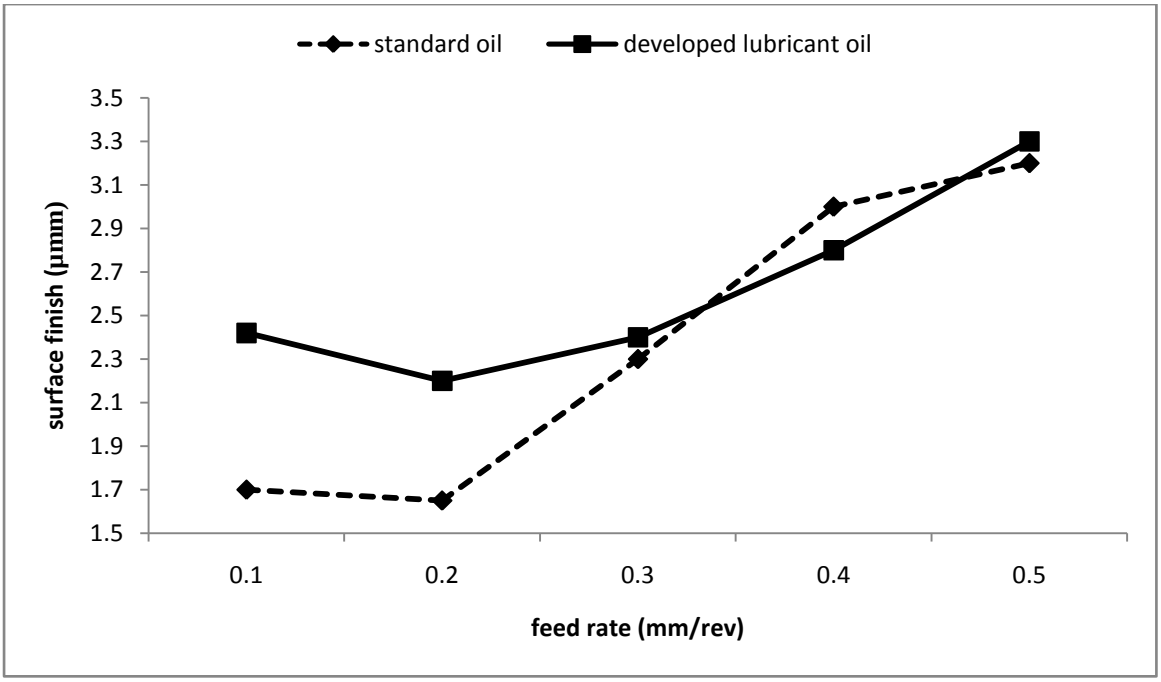


Figure 4.6 Variation of surface finish with feed rate.

Table 4.5: Effect of lubricants on the machining of mild steel when depth of cut is varied and feed rate is at (0.5 mm/rev), speed (180 rpm) are kept constant

Cutting fluids	Depth of cut (mm)	Chip thickness (mm)	Chip thickness ratio	Surface finish (mm)	Temperature (^{0}C)
Conventional cutting fluid	1.0	0.314	0.314	4.50	49.1
	1.5	0.341	0.227	4.80	55.1
	2.5	0.326	0.130	5.00	57.3
	3.0	0.311	0.104	5.30	59.1
	3.5	0.434	0.124	5.75	70.0
Developed cutting fluid	1.0	0.384	0.384	3.5	50.0
	1.5	0.374	0.249	3.75	50.1
	2.5	0.426	0.170	4.00	59.3
	3.0	0.461	0.154	4.50	55.1
	3.5	0.514	0.147	4.70	57.5

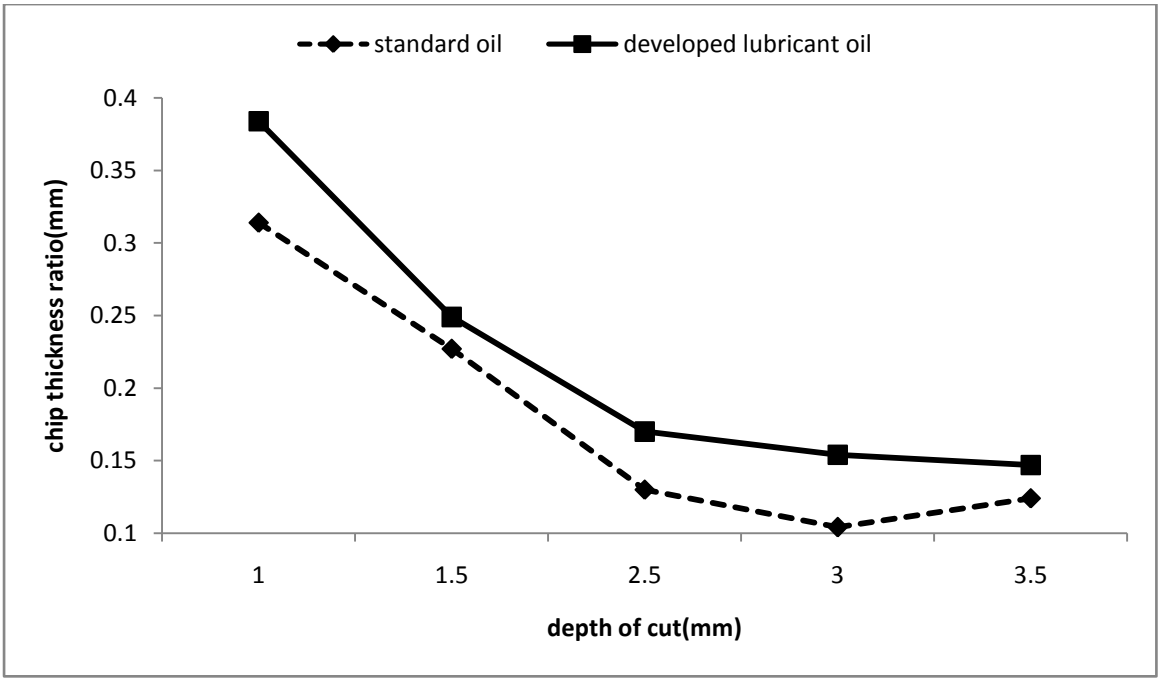


Figure 4.7 Variation of thickness ratio with Depth of cut.

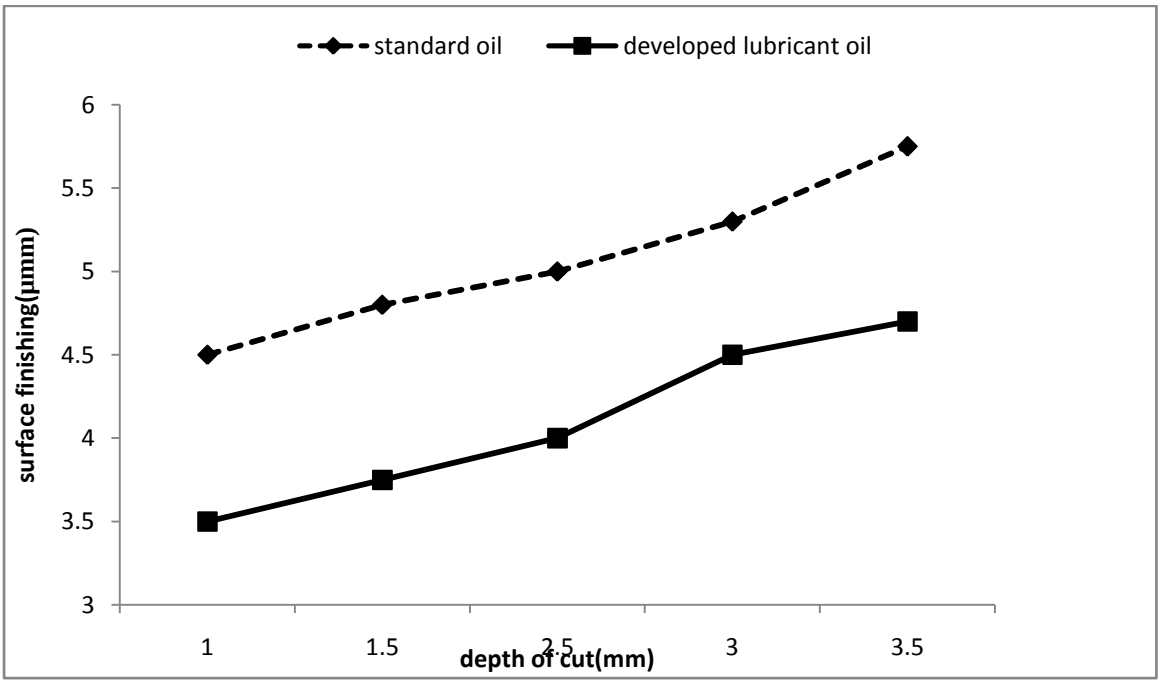


Figure 4.8 Variation of surface finish with Depth of cut.

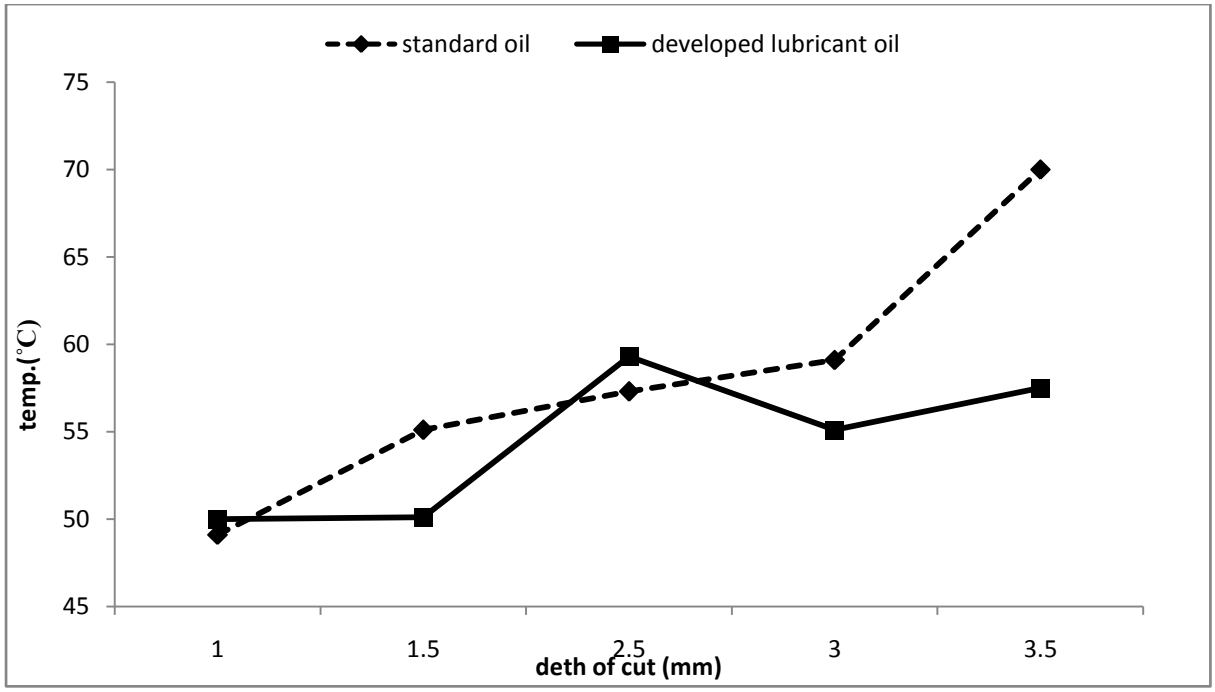


Figure 4.9 Variation of temperature with depth of cut.

4.5 Discussion of Results

4.5.1 Acidic Value

From Table 4.1, it can be observed that the acid value of the oil gives a measure of how corrosive the cutting fluid developed could be to the work piece especially. The acid value of the control sample is higher than the developed cutting oil for use in machining operations involving mild steel. The high acid value of control sample may have been responsible for its high translucent nature above the develop samples. A high acid value promotes emulsification and higher corrosion tendencies**.**

4.5.2 Corrosion Measurement

Plate 4.1 shows two results of corrosion test for standard lubricant and the developed lubricant. As no spots were observed on plate (b), as a result of lubricant additives used. It

can be concluded that the developed cutting fluid has good ability to inhibit corrosion (see Plate 4.1)

4.5.3 Viscosity

Viscosity of the conventional cutting fluid and the developed cutting fluid were analyzed, viscosity accounts for the effectiveness of a liquid fluid to perform lubrication and cooling at the same time developed. High viscous fluids produced thick film lubrication and via-visa. The average viscosity of the developed cutting fluid was found to be 31.1 poise at 29 ^{o}C, while the convectional cutting fluid was 47 poise at 29^{o}C. Low viscosity means high viscosity index, the developed cutting fluid has tendency to be fluid at higher temperature than the convectional fluid

4.5.4 Effects of the lubricants on chip formation

Figure 4.2, 4.4 and 4.7, are graphical representation of Tables 4.3, 4.4, and 4.5 it can be seen that the developed lubricant oil showed relatively high chip thickness ratios than that of standard oil. Thus, high chip thickness ratio is associated with low coefficient of friction; this means the developed cutting fluid aid in reducing friction during cutting. Therefore, this shows that with increase in speed, thickness of chip is first reduced to a minimum and then increased to a maximum after which it drops again. This variation in chip compression is due to the changing values of the actual (working) cutting angle, formation of built-up-edge and variation of coefficient of friction**.** Developed lubricant oil shows a better chip thickness ratio which help in reducing friction at the chip interface, thereby improving the surface finish of the metal (Chapman, 2000)

4.5.5 Effects of the Lubricants on Surface Finish

The graph in Figure 4.8 derived from Table 4.5, shows as depth of cut increases the surface roughness increases. This is due to the plowing effect of the cutting tool. (Chapman2002).

Also, from these graphs the effect of depth of cut on surface finish is lower on the developed lubricant than that of the standard oil.

From Table 4.3 represented on graph of Figure. 4.1 It was observed that as the speed increase the surface roughness reduces due to reduction in friction between the tool flank and the machined surface, high spindle speeds reduce forces and vibration giving better surface finish (Chapman, 2002).

4.5.6 Effects of Lubricants on Temperature

From Table 4.5 represented on graphs in Figure 4.8, it can be seen that temperature increases as speed increases and also as the depth of cut increases, but in the case of feed at constant speed and depth the temperature drops as the feed rate increases. This is because cutting forces decrease with speed and since quantity of heat produced is the product of force and velocity, it follows that more heat would be generated with an increase in cutting speed. Also at low cutting speeds the principal factor affecting tool-chip interface temperature is the deformation at the shear zone, while at high cutting speeds the tool-chip friction is the important factor in the interface temperature. The developed lubricant oil faired best in regulating temperature.

4.5.7 Effect of Cutting Speed on Surface finish and Chip formation

(i) Table 4.3 represented on a graph in Figure 4.1. It was observed that as the speed increase the surface roughness reduces due to reduction in friction between the tool flank and the machined surface, high spindle speeds reduce forces and vibration giving better surface finish (Chapman, 2002).

(ii) Table 4.3 represented on a graph in Figure 4.2. The developed cutting fluid showed relatively high chip thickness ratio than that of the conventional cutting fluid thus, high chip thickness ratio is associated with low coefficient of friction, and this means the developed cutting fluid aid in reducing friction during cutting (Chapman 2002).

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATION

5.1 Conclusions

It has been established that ecology-friendly vegetable-based oil could successfully replace petroleum- based mineral oils as cutting fluid with slight modifications and careful alterations in some of the components of such oils, even better performing cutting fluids could be obtained. The overall results are summarized below:

(i) The cooling property of the developed vegetable-based cutting fluids offers a competitive performance with that of the convectional cutting fluid, as shown by the narrow temperature different of 54.7 ^{o}C using convectional cutting fluid and 53.13 ^{o}C using the developed cutting fluid.

(ii) Chip thickness formed using developed cutting fluid was found to be 0.446 mm which is higher than that of the convectional cutting fluid which is 0.316 mm, the high chip thickness value is probably due to its better lubricating ability, and this allows easier and deeper penetration of cutting tool into work piece and better metal removal rate.

(iii) Viscosity of the convectional cutting fluid and that of the developed cutting fluid were analyzed, the average viscosity of the developed cutting fluid was found to be 31.1 poise at 29 ^{o}C, while the convectional cutting fluid was 47 poise at 29 ^{o}C. Low viscosity means high viscosity index, the developed cutting fluid has tendency to be fluid at higher temperature than the convectional fluid.

(iv) The acid value of convention cutting fluid was found to be 4.57 while that of the developed cutting fluid was 3.85 (See appendix for the calculation). The high acid value of the conventional sample may have been responsible for its high

translucent nature above the developed sample. A high acid value promotes emulsification and higher corrosion tendencies

(v) In corrosion measurement, the developed cutting fluid shows no spots, (see plate 4.1) which means the developed cutting fluid has good ability to inhibit corrosion than the convectional cutting fluid.

(vi) In surface finish measurement, it was concluded that the effect of depth of cut on surface finish is lower using the developed cutting fluid to that of the conventional cutting fluid. Also, it was found that the average surface finish formed using the developed cutting fluid was 3.102 mm while that of the conventional cutting fluid was 3.277 mm. lower value of surface finish indicate a better finishing.

5.2 Recommendation

For further research, qualitative and quantitative analysis on the effects of cutting additives on various oils can also be carried out.

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APPENDIX

Acidic values calculation

Titration: Estimation of acid value

Burette solution: KOH

Pipette solution: Oil + 50ml of neutralized alcohol.

Indicator: Phenolphthalein.

End point: Appearance of pink colour

$$\text{Acid value} = \frac{\text{(vol. of KOH X Normality of KOH X Equivalent weight X 1000)}}{\text{Weight of oil sample in (g)}}$$

Equivalent weight of KOH = 56.1g = 0.056kg

Volume of KOH using the developed cutting fluid = 27.5 ml

Volume of KOH using the convectional cutting fluid = 32.6ml

Weight of oil; sample in (g) = 10g

Weight of oil sample in 1000ml = (10 x 1000)/ (250) = 40g/l

Acid value of the developed cutting fluid

AV= (27.5x 0.1x0.0561x1000)/ (40)

AV = 3.857

Acid value of conventional cutting fluid.

AV = (32.6 X 0.1 X 0.0561X1000)/ (1000)

AV = 4.572