ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

SCHOOL OF MECHANICAL, CHEMICAL AND MATERIALS ENGINEERING

MECHANICAL SYSTEMS AND VEHICLE ENGINEERING PROGRAM

An experimental study on Jatropha Curcas Oil and diesel fuel blend effects on engine components, lubricating oil and carbon deposit

By

Girmachew Ashagrie

A thesis submitted to the department of mechanical and motor vehicle system engineering of Adama Science and Technology University in partial fulfilment of master's degree in Automotive Engineering

June, 2017

Adama, Ethiopia

CANDIDATE'S DECLARATION

I hereby declare that the work which is entitled as "An experimental study on effects of Jatropha curcas oil and diesel fuel blend on engine components, lubricating oil and carbon deposit" is submitted in partial fulfillment of the requirement for Master of Science in Automotive Engineering. It is my own work which I accomplished for my master degree and executed from November, 2016 to May, 2017 with a supervision of N.Ramesh Babu, Associate Professor, Department of Mechanical and Vehicle Engineering, Adama Science and Technology University, Ethiopia.

All relevant resources of information used in this thesis have been duly acknowledged.

Girmachew Ashagrie ________________ ________________

Student Name Signature Date

This is to certify that the above statement made by the candidate is correct to the best of my knowledge and belief. This thesis has been submitted for examination with my approval.

Name Signature Date

1. N.Ramesh Babu. ___________________ _______________

   Main Advisor Name Signature Date

2. Mr. Hadish Teklehaimanot. __________________ _________________

   Co-adviser Name Signature Date

ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

SCHOOL OF MECHANICAL, CHEMICAL AND MATERIAL ENGINEERING

MECHANICAL SYSTEMS AND VEHICLE ENGINEERING PROGRAM

An Experimental study on Jatropha Curcas Oil and diesel fuel blend effects on engine components, lubricating oil and carbon deposit

By

Girmachew Ashagrie

Approved by board of Examiners

______________________________	____________
Chairman, Department graduate committee	**signature date**
______________________________	____________
External Examiner	**signature date**
______________________________	____________
Internal Examiner	**signature date**
______________________________	____________
Advisor	**signature date**

ACKNOWLEDGEMENT

My first and precious thanks belongs to almighty God for all his blessing and strengthen me during hard times in my life.

It is my pleasure to express my gratitude to my supervisor N. Ramesh Babu (Associate Professor) for his generous help from the beginning of the work up to the end reviewing the paper. He advised me how to work with cooperating others, and initiates me to go through difficulties. And I would love to present a great and deep gratitude for my co-advisor Mr. Hadush T/Haimanot for his magnanimous help and support in my work. I have got a good help and support to understand the technical works with him and he always shares me his knowledge.
Dear automotive workshop assistances, laboratory assistants at ASTU chemical department for their help with my work there it pleases me to thank you guys for all your support. And for Ethiopian Petroleum Supply Enterprise especially Mr. Welelaw thank you so much for your help.

Finally, I think it is my duty to express my deepest love and gratitude to my brothers they have been with me all the time and my friends who have been there for me when I needed help and encouraged me. Thank you all!

TABLE OF CONTENTS

ACRONYMS, ABBREVIATIONS AND SYMBOLS

ASTU	Adama Science and Technology University
ASTM	American Standard Testing Material
B20	Biodiesel 20% by diesel 80% blend
JSVO	Jatropha Straight Vegetable oil
ASTM	American Standard Test Method
SAE	Society of American Engineers
SVO	Straight Vegetable oil.
DDO	Distillate Diesel Oil
FAME	Fatty Acid Methyl Ester
CI	Compression Ignition Engine
API	American Petroleum Institute
cSt	Centistokes
VI	Viscosity Index
TDC	Top dead center
BDC	Bottom dead center
IS	Indian Standard
TBN	Total base number
TAN	Total acid number

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

A depletion of fossil fuel source and fluctuating fuel price led researchers to focus on developing new agro-based alternative fuels, which will provide sustainable solution to the energy crisis. The trend of using vegetable oil as an alternative fuel for diesel engine dated late 20th century but until now a research is continued due to its benefit. Straight vegetable oils could be used directly but they need modification in order to minimize their effect on the engine life. Presently, bio-diesels, which are obtained from trans-esterification of straight vegetable oil (SVO), are being used along with diesel in blends. The advantages of biodiesels and vegetable oils are renewability, biodegradability and they are oxygenated. Although many researches pointed out that it might help to reduce greenhouse gas emissions, promote sustainable rural development, and improve income distribution, there are still some resistances exist for using them. Experiment evaluation of the use of several vegetable oils as potential fuel sources is giving a promising result. Initial engine performance tests using vegetable oils were found to be acceptable, while noting that the use of these oils caused carbon build up in the combustion chamber and some engine hard ware wearing. Jatropha is one of the promising vegetable oil. So this paper focuses on the study of the effect of Jatropha straight vegetable oil when it is used as a fuel for diesel engine by blending it with diesel fuel. The objectives of this thesis work was to characterize the fuel and engine lubricating oil after the test conducted and the carbon deposit formation and engine component wearing measured. And its scope was on diesel engine fuel from preparing a blend of Jatropha straight vegetable oil with diesel fuel and run an engine test so that finally measure and quantifying the effects of the fuel blend. The methodology of the study starts from careful identification of the methods which has been used to blend fuels with alternative fuels and after preparing the experimental set up. After the blending the test on diesel engine runs for 75 hours. After the test or the experiment has been executed measuring the effects of the blended fuel on engine components and engine lubricating oil has been measured and finally the effects due to the blend fuel has been compared to the straight vegetable oil and diesel fuel. In this thesis work a test has conducted using Jatropha curcas oil and diesel fuel blend with a proportion of 20/80% and using a single cylinder direct injection diesel engine (DY-23 engine). The physio-chemical properties of the fuel and the lubricant property after the engine runs for 75 hours has been characterized. Wear of the engine parts and the carbon deposit formed are measured and reported. Finally around 7.74g of carbon deposit has been found which is less than that of straight vegetable oil which is above 13.54g of carbon deposit is formed. promising result has been obtained to use Jatropha curcas oil by blending up to 20% and it is recommended that preheating the fuel would be great to minimize the unwanted effects on the engine life.

Key words: straight vegetable oil, blended fuel, lubricant oil, carbon deposit, engine wear.

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

At first the innovation of internal combustion engine and fossil fuels were very welcomed and it was the greatest technological and scientific development by the time. However, when the number of vehicles around this wide world increases led to the depletion of petroleum reserves and an increase in environmental pollution. Limited reserves of fossil fuels and environmental pollution concerns have resulted in increased interest in renewable low polluting alternative fuels.

It is known that, many studies have been studied around the world to develop a better alternative fuel or energy source which can substitute petroleum fuels for the designed engine. Different type of alternative fuels have found recently from different sources. These findings may minimize the frustrations due to the limited reserve of petroleum fuels. And also helps to control the fluctuating cost of petroleum products. Furthermore to reduce the effect of environmental pollution due to petroleum fuels. Many alternative fuels are produced recently such as biodiesels, alcohols, hydrogen, even electricity uses as an alternative fuel.

Since most countries are importing petroleum fuels and the price of these petroleum fuels is fluctuating, it led to growing interest in using biodiesel, an alternative fuel made from vegetable oils. Some countries have expressed their interest in using straight vegetable oil (SVO), or waste oils from cooking and other processes, as fuel. These oils seem to be appealing because they are obtainable from agricultural or industrial sources without intermediate processing. However, SVO and other waste oils are generally not considered acceptable vehicle fuels for large-scale or long-term use due to their side effects on engine life of the vehicle.

The use of biodiesel and vegetable oil fuels is dating back to 1892 when Rudolf Diesel demonstrates his new innovation diesel engine using peanut oil as fuel. Using such oils can reduce environmental pollution, fuel price fluctuation, and have some other advantages. Rudolf Diesel envisioned using vegetable oil as a fuel of his engine, as he stated in his 1912 speech saying "*the use of vegetable oils for engine fuels may seem insignificant today, but such oils may become, in the course of time, as important as petroleum and the coal-tar products of the present time*" from Chasen & Fasano, 2009. At the 1900 World Exhibition in Paris, a diesel engine was demonstrated running on peanut oil. In fact, the general feeling in the early 20th century was that vegetable fuels would be the primary fuel for diesel engines, and biodiesels were widely used until the 1920s.

However, during the 1920's, diesel engine manufacturers altered their engines to utilize the lower viscosity of fossil fuel, best known as petro diesel, rather than to run on biomass vegetable oil fuel. The first patent of biodiesel fuel derived from palm oil was granted in 1937. In 1938, J. Walton promote the use of FAME (Fatty Acid Methyl Ester) from which glycerol had been removed discussed by Chasen & Fasano, 2009. During the shortage of fuel in 1970’s and 1980’s, interest in alternative fuels was again revived.

Biodiesel is a mono-alkyl ester of fatty acid which can be derived from vegetable oil or animal fats. Among those vegetable oils Jatropha straight vegetable oil can be directly used in diesel engine. The basic composition of this compound is triglyceride, which consists of three fatty acids and one glycerol molecule. Biodiesel can be obtained when this vegetable oil reacts with alcohol to produce mono-alkyl ester.

According to Many studies involving vegetable oils as a primary source of energy particularly, during the early 1980's, confirms that the possibility of using unmodified vegetable oils as a replacement for diesel fuel and there is no question that vegetable oil can be placed in the tank of a diesel powered vehicle and the engine will continue to run and deliver acceptable performance [32].

Despite the success when diesel engines are operated on vegetable oil for short term performance tests, the real measure of success when using vegetable oil as a diesel fuel extender or replacement depends primarily on the performance of vegetable oils in engines over a long period of time [28].

The viscosity, chemical and physical property differences between SVO and the diesel fuel for which direct injection diesel engines are designed, lead to several issues and the unburned fuel buildup can infiltrate the engine lubrication oil, potentially leading to the engine wear[17].

The major causes of engine malfunction due to lubricant quality are deposit formation, contamination, oil thickening, oil consumption, ring sticking, corrosion and wear. The environment in which it operates affects lubricant stability. Factors such as temperature, oxidation potential and contamination with water, unburned fuel fragments and corrosive acids limit the useful life of a lubricant. This is the area where additives have made a major contribution in improving the performance characteristics and extending the useful life of lubricants.

1.2 Problem statement

In many studies it is reported that vegetable oils are becoming the promising substituent of diesel fuel and Jatropha curcas oil is among them. Jatropha straight vegetable oil can be used directly to substitute and perform as a diesel fuel mostly for stationary diesel engines. But from the studies it is observed that using the vegetable oil directly without any modification on them will cause shorter engine life. This early failure of the engine is due to the properties of the straight vegetable oil. Some published literatures indicate that using straight vegetable oil can extremely affect the engine life. To avoid such a problem basically the researchers work on modification of engine itself or modification of vegetable oil properties.

Modification of engine design is the best solution to use these alternative fuels but modifying the engine and make it compatible with the fuel is very tedious, complicated, and not economical. There are some methods of modifying properties of vegetable oil to use as a fuel but some of them are very complicated and need huge plant and long processes. Engine component wear and the formation of carbon deposit are the major causes which extremely affects the life of the engine.

The effects on engine components and engine oil induced while using straight vegetable oil and the formation of carbon deposit has been studied by researchers. For those studies which are conducted using straight vegetable oils they suggest that the problems found while using SVO may be minimized if we modify the vegetable oils. In this thesis work, a blend of Jatropha curcas oil and diesel fuel with a ratio of 20% by 80% is used to run the engine and study the effects on the engine components, engine oil and the amount of carbon deposit formed.

1.3 Objective of the study

1.3.1 General objective

The general objective of this thesis work is to study the effect of Jatropha curcas oil and diesel fuel blend on engine lubricant, wearing effect on engine components and carbon deposit formation inside the diesel engine.

1.3.2 Specific objectives

The specific objectives of the study are:

- To characterize the properties of B20.
- To characterize the properties of lubricating oil after 75 hours run.
- To measure the wear of engine parts.
- To measure the carbon deposit.

1.4 Significance of the study

Recently using blends of vegetable oils and biodiesels become common to use as diesel engine fuel in diesel engines without any major modification of engine, engine materials or engine oil. Studies have shown that JSVO is proved to be an alternative fuel to diesel engine. But as much as it is useful it also cause engine early failure due to its difference in composition with petroleum diesel fuel.

So, some modification to the engine hard ware and operating system can solve the problem but it may take too long time. Therefore, this type of study can reduce the time and cost it takes to modify engine design. By preparing good blend of SVO and diesel fuel it is possible to minimize the effects of SVO to the engine components and engine lubricating oil.

- To the people and the country it reduces the cost of the fuel and the amount of the petroleum diesel imported.
- To those who use Jatropha vegetable oil for their diesel engine to indicate how they extend the life of the engine by reducing component wearing.

- To the company’s it reduce the time and tedious work of modifying engine design for vegetable oils.

1.5 Scope of the study

The scope of this study includes preparation of blend (B20) of Jatropha curcas oil and diesel fuel and running a test on small scale diesel engine to investigate the effects of it on the engine components and engine oil. And disassembling the engine after testing the blend with diesel engine. Measuring wear of engine components and the amount of carbon deposit. It also covers the characterization of the fuel B20 and the lubricant oil after test is conducted.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The reliance and the fluctuation of fuel price and also the depletion of fossil fuel led to growing interest in alternative fuels which could be made of vegetable oils. However, there is also an interest to use straight vegetable oil (SVO) or raw vegetable oil (RVO) directly without any intermediate process or any change. The development of biofuel sector gives a hope for the countries those which implement it [1].

Many vegetable fuels are being investigated as potential substitutes for the current high pollutant diesel fuel derived from diminishing commercial sources. Vegetable oils may provide one such alternative and their potential has been examined in the past years by several researchers. Many of the researchers have indicated that the successful use of vegetable oil is a function of engine type. Vegetable oil cannot be safely used in an indirect injection naturally aspired and air cooled engine for long periods of time.

This problem is related to the high viscosity of vegetable oils which causes in adequate atomization and incomplete combustion. Another problem associated with the use of vegetable oil as a substitute of diesel fuel is the reactivity of the unburned fuels, which is the cause of fouling in injector nozzle and cylinder deposition. A major problem to be encountered with the more widespread use of the diesel engine, however, is the emission of particulate matter which is smoke comprising carbon and unburned hydrocarbons. This has been the subject of much recent public concern over possible effects on human health, and particularly respiratory disorders in urban environment [2] and [3].

Studies show that one alternative and demonstrable effective way of reducing the emissions of smoke and oxides of nitrogen is to emulsify the vegetable oil fuel with a small proportion of water. This leads to improved atomization and lower-combustion chamber temperature. A way of reducing the viscosity of the vegetable oil fuel is to blend it with some proportion of diesel fuel by volume or/and preheating the vegetable oil before it is admitted to the combustion chamber. Some researchers in different country made efforts to use vegetable oil as a diesel fuel substitute with minimal fuel processing and no engine modification. To take advantage of emulsification as a way of improving the combustion of vegetable oil in diesel engine, some amount of water could be introduced in the vegetable oil during the extraction process. The performance of Jatropha/diesel fuel blends in a diesel engine has also been studied [4].

2.2 Production of Jatropha vegetable oil

Before extracting we need to identify what Jatropha tree seems like, [5] and [6] reported that the general description about the Jatropha tree and it is a large shrub with 3-5 meters height and could grow 8-10 meters height with a comfortable environmental condition as shown below on figure 2.1. The branches of the tree contain latex, roots are formed from seeds, one central and four peripheral. Cuttings, when planted do not form tap root. The plant is monocots and flowers are unisexual. As [5] referred the life span of the plant is more than 50 years.

Figure 2. 1 Jatropha tree hedge around a homestead **[5]**.

The extraction and production of Jatropha vegetable oil has been reported by different researchers at different time. [7] Indicated that the oil content by weight for Jatropha dry seed is around 55%. However, the extraction method which has been used for production of Jatropha vegetable oil from Jatropha seed and the feed stock quality of the production process affects the amount of oil produced. Even though, some researchers discussed three types of production methods but [7] identified that there are two main methods of extracting the oil. According to this study the two main extraction methods are the chemical extraction method which uses some solvent as an extractor and the mechanical extraction method by using either a manual mechanical press or an engine driven-expeller.

Different papers discuss that the type of the extraction method gives different results among those [8] has reported that the first type which is solvent extraction method with n-hexane could produce about 41% yield by weight from Jatropha seed. In [9] it is reported that around 30 or 38% oil could be extracted by using engine driven expeller from dry seed of Jatropha and in their study 30.8% of oil was extracted from 12,782 tons dry seed in Nicaragua.

In [10] it is reported that using a simple mechanical cracking machine and screw-press oil extraction process. After the harvested Jatropha fruit was dried for three to four days before cracking figure 2.2 shows the fruit and seed of Jatropha. Then the dried fruit about 150 kg was fed into the cracking machine. About 41.8 kg of seeds was obtained after cracking Jatropha seeds. And using screw-press machine it results 11.71 kg Jatropha oil and 30.09 kg press cake. It means about 28% of crude oil by weight per kg of the Jatropha seed has been extracted.

Figure 2. 2 Jatropha fruit and Jatropha seed

2.2.1 Mechanical manual Ram-pressing method

The mechanical ram pressing method of oil extraction is the one method which is currently used for many studies from [11] discussed the process of extraction starting from shelling which is the removal of seen coat at the beginning up to the end production of the oil which is filtration of the oil from solid particles of the waste product and some other additives. Figure 2.3 below shows the production process using ram pressing extraction process.

As it is shown from the flow chart the next step after shelling is milling which is the uncoated seed of Jatropha is milled in to dough by using corn mill machine. After milling the moisture content of the oil has to be determined and it must be 12% wet bulb. If not water will be add or remove to reach 12% wet bulb moisture content. After the moisture is set the rolling process will continue to make the dough to balls of 1 kg by weight.

Then the rolled dough which are the balls are heated up to 75-80^{0}C by pacing items in to an oven so that the temperature of the rolled balls raised. This process makes the extraction of oil easier while the dough and balled goes through the ram-press machine. The pressing process extract the oil from the balls and after the pressing the oil will passes under some filtration process by using another machine (figure 2.4) and the final Jatropha vegetable oil is well filtered.

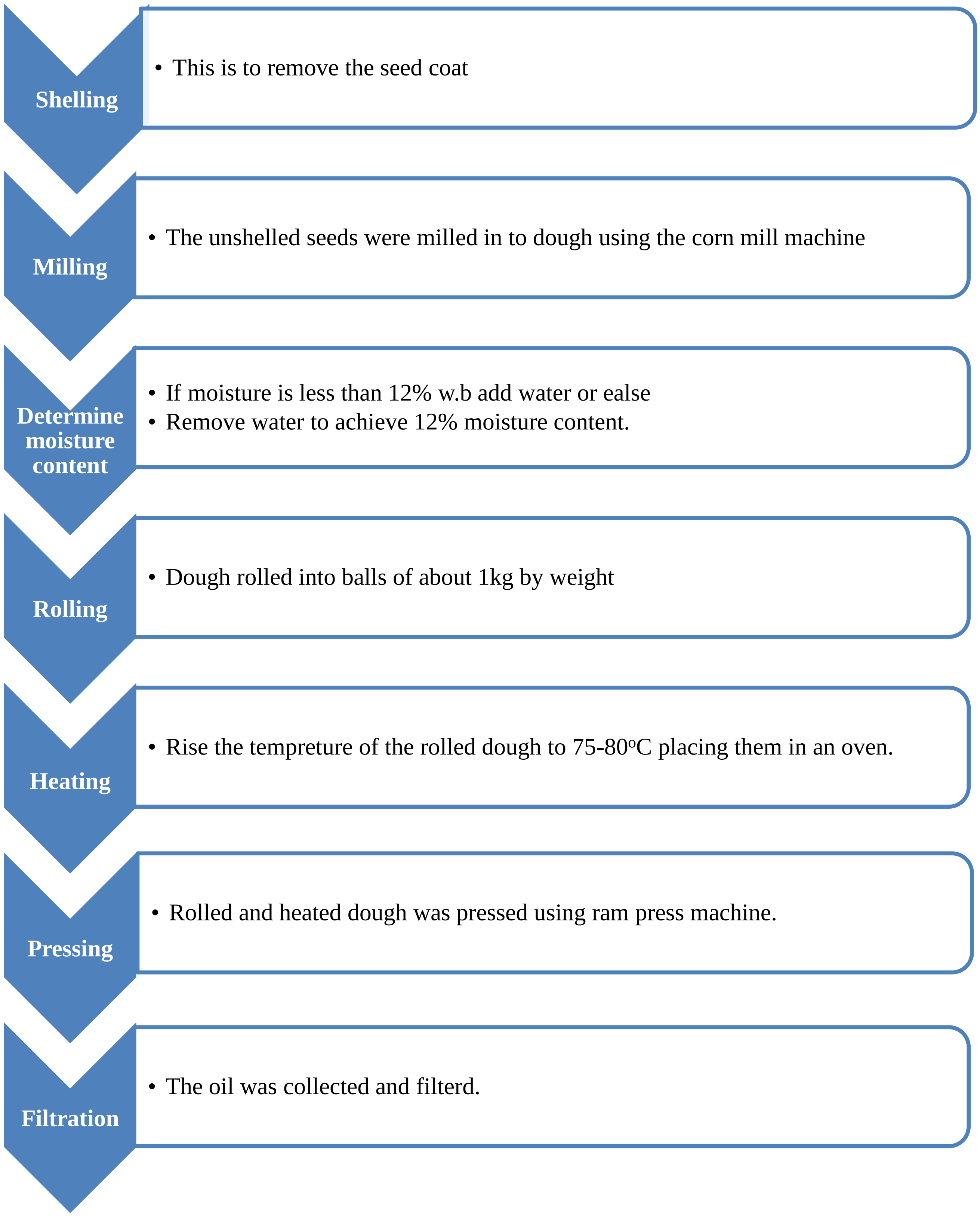


Figure 2. 3 Flow chart for oil extraction using the mechanical ram-press **[11]**.

Figure 2. 4 Oil filtration machines for crude Jatropha oil

2.2.2 Mechanical engine driven expeller pressing method

An electrified press machine shown below figure 2.5 could be used for production of vegetable oil in some countries. The aim of the pressing process is to separate the oily phase from the solid phase of the seed material. In large-scale facilities, two different pressing techniques are used for the separation of oil from the seed. The first one is pre-pressing of the flaked seeds which leave about 15–20% oil in the press cake. Today, this is the commonly used technique, which is followed by the extraction of the press cake by solvent. The advantage of pre-pressing is that a press cake is formed from the small flakes which allow a good solvent contact and percolation in the extractor. The result is an optimized removal of oil from the seeds. Extraction by combining screw press and solvent extraction has the economic advantages – low costs using a screw press and higher oil yield using solvent extraction [12].

Figure 2. 5 Press machine for production of Jatropha oil used in Zambia

The other technique is a more extensive pressing of the oilseed without further extraction by solvent. This straight pressing is interesting for oilseeds with high oil content, where it is no problem to get over the release of some percent of oil in the residue. Nowadays, this method is used only barely in large-scale facilities since it is not possible to reduce the oil content to less than 5% oil in the press cake by this technique. From an economical point of view, this is not sufficient for this type of oil mill. Nevertheless, this technique has the advantages of lower investment and maintenance costs and of achieving higher oil quality. [13]

2.2.3 Chemical extraction method using solvent n-hexane

Some researchers reported that the assumption on the content of oil in dry seed of Jatropha is 55% and they discussed that the efficiency of extracting it from the seed is higher while using solvent extraction with n-hexane than mechanical press method [5].

In [6] it is reported that the oil yield for Jatropha seed depends on the method of extraction; it is 28–32% using presses and up to 52% by solvent extraction. Also it is described as non-edible oil since the seeds are toxic. In [6] the toxicity of Jatropha is due to the presence of curcasin (a globulin) and Jatrophic acid (as toxic as ricin).

Despite its explosiveness of n-hexane while exposed to or contacts with oxygen it is highly recommended that under a controlled processing the extraction efficiency of this solvent is very high due to its cost is cheap and its chemical property. The basic properties used for oil extraction with n-hexane is that its high solubility with oil at low temperature, has an appropriate boiling temperature, noncorrosive to metal, does not react chemically with the oil, stable under the process conditions, not mixable with water, which eases the separation of water from the seeds, and it is easily and completely removed from the residue with low energy input and without impairment of the raw oil. But it is also discussed that using n-hexane has some disadvantages related with safety [12].

2.3 Physical and Chemical property of Jatropha vegetable oil

The physical and chemical properties of many vegetable oils and petroleum diesel oils are very extremely different when we compare each other. Vegetable oils are unlike diesel oils they may be edible or they might be non-edible like petroleum diesel oil. Basically vegetable oils are driven from plants so they are lipid in their form. Even though they can be used for diesel fuel substituent due to their chemical structure they are not comparable with diesel engines like diesel fuels. Petroleum based diesel contain only carbon and hydrogen atoms arranged in straight chain or branched chain structures, and aromatic configurations. Diesel fuel normally can contain straight or saturated and unsaturated branched chains of hydrocarbon but vegetable oils contain different alkyl groups of long chain these long chains may cause oxidation problem [14].

From [15] it is discussed that in large sized vegetable oil molecule the presence of oxygen mainly affects the fuel properties of different vegetable oils and make them unsuitable to run diesel engines. Vegetable oil consists of about 97% triglycerides; the remaining 3% for di-glycerides, mono-glycerides and free fatty acids. Chemical structure of triglyceride molecule found in many vegetable oils is represented as shown below in the Figure 2.6. Structurally, triglyceride is a reaction product of a molecule of glycerol with three fatty acid molecules, yielding three molecule of water and one molecule of triglyceride [15].

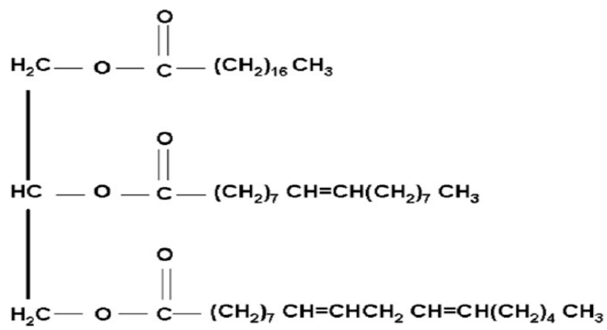


Figure 2. 6 A structure of typical triglyceride molecule **[16]**.

According their characteristics of a variety of vegetable oils fall within a narrow band and are closer to those of diesel oil. According to studies, the kinematic viscosity of vegetable oils lie's between 30 and 60 cSt at a temperature range of between 20 and 40^0c. Vegetable oils have high molecular weights, which are three or more times higher than diesel fuel due to this and their chemical structure they have high viscosity. The flash point of vegetable oils is also very high (>200 ^{0}C). Their heating value is at the range of 36-40 MJ/kg, which is comparatively lower than that of diesel fuels (42-46 MJ/kg). This is because the presence of chemically bonded oxygen in vegetable oil lowers heating value by about 10%. Cetane number is in the range of 32-40, while the iodine value ranges from 0 to 200, depending upon unsaturation. The cloud and pour point of vegetable oils are higher than that of diesel fuel [7]. Key properties of Jatropha oil and diesel are summarized in Table 2.1 below.

Advantages of vegetable oil as engine fuel lie in their renewable nature and wide availability of sources and their economic advantage for petroleum importing countries like Ethiopia. This is particularly attractive to countries lacking source of liquid fossil fuels. It can also be produced on small scale for on-farm operation to run tractor, pump and small engine for power generation. Such fuel contains potential for lower contribution on combustion to the atmospheric concentration of carbon dioxide than from the fixed carbon in fossil fuel. It is clear that the use of vegetable oil as fuel in diesel engine depends upon their physical and chemical properties, and on their combustion characteristics as well as the type of engine used and operating conditions [8].

Table 2. 1 Physio-chemical properties of diesel and Jatropha vegetable oil **[17]**.

Property	Diesel oil	Jatropha oil
Density (kg/m^3)	830	918
API gravity	37.15	22.81
Kinematic viscosity at 40^oC (cSt)	2.5	37
Cloud point (^oC)	-12	9
Pour point (^oC)	-17	4
Flash point (^oC)	70	238
Calorific value (KJ/kg)	42,200	37,500
Carbon residue (%,w/w)	0.05	0.8
Ash content (%,w/w)	0.01	0.04
Carbon (%,w/w)	86.71	77.21
Hydrogen (%,w/w)	12.98	10.25
Nitrogen (ppm)	5	3
Oxygen (%,w/w)	0.31	12.52
Sulfur (ppm)	340	8

From studies to use such vegetable oils for diesel engine as an alternative fuel the physical and chemical properties has to be modified to make it suitable for the engine. The fuel has to be modified to bring their combustion properties closer to diesel. This fuel modification is mainly aimed at reducing the viscosity to eliminate flow and atomization related problems. It can be modified in four ways listed below.

1. Pyrolysis/Thermal Cracking
2. Dilution/blending,
3. Micro-emulsion,
4. Trans-esterification.

2.3.1 Pyrolysis/Thermal Cracking

In the absence of oxygen a thermal treatment can be used to alter the physical and chemical properties of vegetable oils and the process is called pyrolysis. In [18] it is discussed that other means of achieving a change in chemical and physical property is using some catalyst in the process of pyrolysis. Vegetable oils can be cracked to shorter chain alkanes, alkenes, aromatic hydrocarbons and carboxylic acids some of which may be suitable for use in diesel engines [19]. In [20] it is reported that a successful pyrolysis of soy bean oil, cotton seed oil and other vegetable oils to obtain alkenes aromatic hydrocarbons and carboxylic acids which had lower viscosities, flash point and equivalent calorific values.

2.3.2 Blending or Dilution

This is the physical process of preparing a solution of vegetable oil and mineral diesel. The sole purpose of this process is to reduce the viscosity and to alter other properties of the vegetable oils according to [21] and [22]. According to the study under [11] blending has an additional advantage of increasing the calorific value of the vegetable oil and brings it close to diesel oil. A report on [22] that the calorific values of blends of B5 (5% Jatropha and 95% Kerosene), B10 (10% Soybean and 90% kerosene) and B5 (5% Palm oil and 95% kerosene) were actually higher than that of kerosene. This was however not corroborated by in a similar study. It is also reported that the calorific value of B5 (5% Jatropha and 95% kerosene) as coming close to that of kerosene and not above it.

Many researchers have conducted test of blends of vegetable oils and diesel on CI engines and findings reported are equally many and varied. On [21] it is reported that coconut oil blends with diesel can replace diesel in CI engines in spite of lower engine speeds and higher fuel consumption for a given power output.

In [23] also reported that up to 50% of diesel could be replaced with Jatropha without any major operational difficulties. He however advocated for a long term durability test like a researcher [24] reported that a straight vegetable of Jatropha curcas oil used for endurance test and the engine used stopes after working for 69 hours and finally he suggested that Jatropha oil could be used for diesel engine substituent with some present of blending. Engine failure in engines with 50% vegetable oil in long term durability test has been reported by some other researchers.

Now a days the attention of researchers engaged with the issue of optimal blend of vegetable oil and diesel. In [11] it is reported that 2.6% Jatropha and 97.4% diesel was the optimum blend giving higher performance characteristics more than diesel alone. Other researchers have reported different values using same and different vegetable oils. In [19] reported 50% linseed oil blend to be the optimum whiles 30% mahua oil was reported by the same researchers as being more thermally efficient. 20% rice bran oil blend with diesel was also reported by [22] to have minimum brake specific fuel consumption.

In many papers it is reported that 10% Jatropha and 90% diesel as having the lowest fuel consumption rate and efficiency higher than that of pure diesel alone at mid loading conditions of 41.55N and a corresponding torque of 4.77Nm. Using blends of cotton seed oil and conventional diesel, concluded that 30% cotton seed oil and 70% diesel was optimal in terms of thermal efficiency and stability of fuel. Engine test conducted by Sims, as reported in [25] using blends of rape seed oil and diesel indicated that 50% substitution of diesel did not lead to any significant power loss.

However, long durability test showed injector pump failure and cold starting problems. [25] Also reported that 25% and 50% Crude Palm oil (CPO) suffered power loss under light load and comparable power under high loading conditions. After an extensive literature review, Peterson and Jones (2001) concluded that engine durability was questionable in blends containing more than 20% vegetable oil; however, more research should be conducted to see if 20% or less vegetable oil could be used as a fuel extender.

One can see that results reported by various researchers using different vegetable oils blended with diesel and other fossil fuels are quite different in different aspects and the advantages of vegetable oils. The logical question to ask then is; does the optimal blend depend on the source of vegetable oil or other factors may contribute to it? And is it economical to blend vegetable oils to use for diesel engines?

In terms of economics, blending of vegetable oils have been reported by Cloin (2007), as being relatively cheaper to produce than trans-esterifying the vegetable oil to produce biodiesel and also to redesign the engine. And in [26] it is discussed that diesel can be blend with ethanol and at different ratio and the emission could be reduced at high speed and the performance can be developed. If ethanol could be blended with fuel why not vegetable oils could be blended and give such a good result due to their property which is very comparative with diesel.

2.3.3 Micro-emulsion

The process called Micro-emulsion is a formation of micro emulsions (co-solvency) is one of the four potential solutions for solving the problem of vegetable oil viscosity. Micro emulsions are defined as transparent, thermodynamically stable colloidal dispersions in which the diameter of the dispersed-phase particles is less than one-fourth the wavelength of visible light [27] .

In [19] it has been proposed and investigated as a remedy to the problem of high viscosity of vegetable oils. The dimensions of the fluid microstructures are in the range of 1-150nm. Some literatures reported that higher fuel consumption, similar power producing capability and higher thermal efficiency at higher loads for micro emulsion of ethanol and mineral diesel. Though micro-emulsions are reported to improve spray characteristics by explosive vaporization of the lower boiling constituents [19] and it is reported that micro-emulsions are difficult to produce and do not provide consistent result.

2.3.4 Trans-esterification

The reaction between a triglyceride and an alcohol (ethanol or methanol) in the presence of a catalyst (NaOH or KOH) to produce an ester also known as the production of biodiesel in some literature and glycerol is known as trans-esterification as shown on figure 2.7 below. Trans-esterification has been reported to be the best method of utilizing vegetable oils in CI engines and the process is reversible [20] and [19]. The quality of the fuel is greatly improved when trans-esterified as the viscosity of the oil is considerably reduced whiles improvement in Cetane number has also been reported [20] and others.

According to some studies [28], eleven percent of biodiesel is oxygen thus complete combustion is assured as compared to diesel. Trans-esterification is often considered expensive especially for an agrarian economy like Ethiopia and other countries [5] at the moment, all the possible raw materials except the vegetable oils will have to be imported and since the local technology is very rough and backward. In spite of the fact that biodiesel fueled vehicles do not require significant modification to the engine the process of transfection is advantageous but trans-esterification process is very costly due to its additional process and equipment's it also require a huge company.

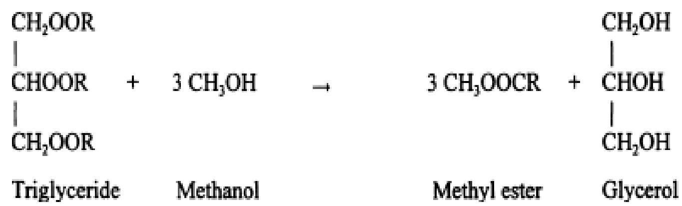


Figure 2.7 Structure of triglyceride and transesterification reaction **[20]**.

2.4 Production of bio-diesel from vegetable oil

Biodiesel is a liquid biofuel obtained by chemical processes from vegetable oils or animal fats and an alcohol that can be used in diesel engines, alone or blended with diesel oil [6].

The process used to produce biodiesel is called transesterification as it is discussed on 2.3.4. In [29] the process of transesterification is defined as an ester reacts with an alcohol to form another ester and another alcohol. The most efficient catalysts for this reaction are KOH or NaOH. Three mole methanol's react with one mole triglyceride which produces mixture of fatty esters and glycerin. The industrial-scale processes for transesterification of vegetable oils were initially developed in the early 1940s to improve the separation of glycerin during soap production [29]. The reaction is described with a chemical reaction diagram in the Figure 2.8 below. Where the representation of R is for a long chain hydrocarbon mostly called fatty acid chain.

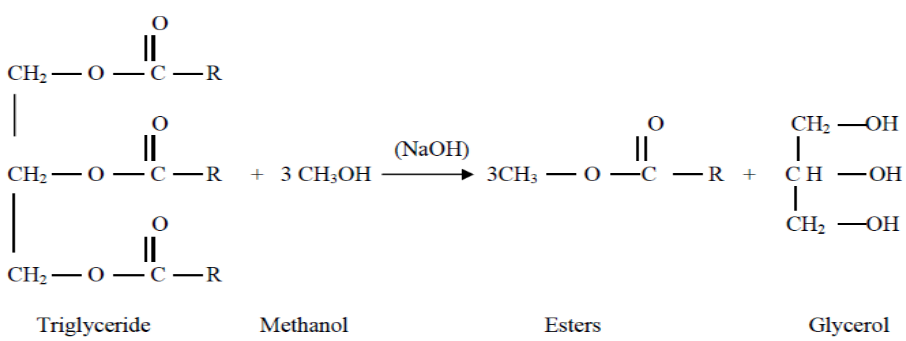


Figure 2. 8 A chemical reaction of biodiesel production **[29]**.

This chemical reaction converts an ester which is triglyceride from vegetable oil into a mixture of esters of the fatty acids that makes up the oil and glycerol. Biodiesel is obtained from the purification of the mixture of fatty acid methyl esters (FAME). This process it accelerated using catalysts and according to the catalyst used the process can be called acidic, basic and enzymatic [30], [31] and [32] .

2.5 Vegetable oil and diesel fuel blending

It is not new to use vegetable oil for internal combustion engine especially for diesel engine. The advantages of vegetable oils as a fuel for IC engine is been studied. Since it can be produced domestically with three simple methods it helps to reduce once country petroleum import cost, and the important behaviors of vegetable oil is biodegradable, nontoxic, contains low aromatics and Sulphur contentment than petroleum diesel. It is known that vegetable oils are environment friendly [16].

Without modifying the engine or engine component it is useable [33]. However there are some problems and challenges with related to the cost and the primary choice of vegetable oils either for food or fuel. The conflict of Food-fuel on vegetable oil is the very concerning issue. Since Jatropha oil is non-edible oil the food-fuel conflict is no longer a problem with it. It is known that at low temperature the viscosity of vegetable oil can Couse a serious problem for the engine. For such a problem blending with diesel oil and heating it before using it could be the solution.

Researchers study the possibilities of operating diesel engine with different vegetable oils such as [16], [34], [35] and [36]. [16] Have seen a great potential for substituting different vegetable oils and investigate on diesel engine and on his report shows that there were acceptable fuel potential. To replace diesel oil with vegetable oil, many researches and testes has been done during 1980's, 1990's up to now. To determine the best suited vegetable oil for diesel engine [34] studied the characteristic properties of eleven vegetable oils.

Research on vegetable oil use in diesel engine is still progressing today. A study by [37] presented the results of exhaust emissions characteristics of ordinary Malaysian coconut oil blended with conventional diesel oil in a diesel engine. The results showed that the addition of 30% coconut oil with diesel oil produced higher brake power with a net reduction in exhaust emissions.

The experiments were undertaken by [38] to test a diesel engine using oil composed of cottonseed oil and conventional diesel fuel. The experimental results showed that a mixing ratio of 30% cottonseed oil and 70% diesel was optimal in ensuring relatively high thermal efficiency of the engine. Research published by [39] briefly reviewed the use of hazelnut oil as an alternative fuel in pre-chamber diesel engines, and compared it with diesel. The results showed that the hazelnut oil may be employed in most diesel operating conditions in terms of the performance and emission parameters without any modification or preheating of the fuels.

An experimental investigation has been carried out to analyze the performance and emission characteristics of a CI engine fueled with Karanja oil and its blends with petroleum Diesel (K10, K20, K50 and K75) by [22]. The effect of temperature on the viscosity of Karanja oil has also been investigated. A series of engine tests, with and without preheating have been conducted using each of the above fuel blends for comparative performance evaluation. The results of the experiment in each case were compared with baseline data of diesel fuel. Significant improvements have been observed in the performance parameters of the engine as well as exhaust emissions, when lower blends of Karanja oil were used with preheating and also without preheating. Karanja oil blends with diesel (up to K50) without preheating as well as with preheating, can replace diesel for operating the CI engines, giving lower emissions and improved engine performance.

A study on [40] investigated raw rapeseed oil (RRO) and its blends (RRO20 and RRO50) in a DI diesel engine. The effects of fuel preheating to 100°C on the engine performance and emission characteristics of a CI engine, fueled with rapeseed oil diesel blends were clarified. Results showed that preheating of RRO lowered its viscosity and provided smooth fuel flow.

It can also be concluded that preheating of the fuel has some positive effects on engine performance and emissions when operating with vegetable oil. [33] Reported that by using a heat exchanger, preheated Jatropha oil has the potential to be a substitute fuel for diesel engines. Optimal fuel inlet temperature was found to be 80°C considering the brake thermal efficiency, brake specific energy consumption and gaseous emissions. A comparable engine performance and emissions are reported by [41] using preheated peanut, sunflower and canola oils in two DI diesel engines.

Seven non edible vegetable oils has been reviewed in [42] including Jatropha oil as an alternative fuel for diesel engine. Jatropha oil was identified as a leading candidate for the commercialization. The scientific name of Jatropha is Jatropha curcas L. and Jatropha oil is one such kind of non-edible vegetable oil. Not only does Jatropha have a yield of well over 200 gallons of oil per hectare per year, eleven times that of corn (Khan et al., 2009), it also increases the fertility of the land on which it is grown so that it can potentially be used for food crops in subsequent years. Jatropha is a perennial which can grow in arid conditions on any kind of ground, and does not suffer in droughts or require irrigation. Therefore, unlike the common biofuel crops of today (corn and sugar); they are very easy to cultivate, even on poor land.

Jatropha is fast growing, begins yielding oil in the second year and continues for forty to fifty years [43]. Optimal yields are obtained from the sixth year. [44] Investigated Jatropha oil and its methyl ester to find out their suitability for use as petro-diesel. Different properties of Jatropha oil were experimentally determined and compared with theoretical equations developed in the study. The study suggested that Jatropha oil can be used as a source of triglycerides in manufacture of biodiesel cost-effectively. [23] Investigated Jatropha oil in a diesel engine. Acceptable thermal efficiencies of the engine were obtained with blends up to J50. The study under [11] examined the performance of Jatropha oil blends in a diesel engine. The most significant conclusion from the study was that the J2.6 produced maximum values of brake power and brake thermal efficiency as well as minimum values of specific fuel consumption. In papers [22] and [40] it is indicated that the successful use of Jatropha oil is a function of engine type, and percentage of Jatropha oil in the blends.

This study was therefore [43] undertaken at the Asian Institute of Technology (AIT), Thailand to gather information on the behavior of a diesel engine when operated with Jatropha oil and its blend with diesel at different proportions. The objective of this study was to identify the best Jatropha-diesel blends, for which the engine performance is similar or better than that of diesel fuel.

From the literature [21] it is discussed that the density of diesel oil lies between the range of 0.836-0.850 and the density of SJVO is 0.9392 also the kinematic viscosity is between 4-8 for diesel and 52.76 for SJVO. Blending this fuels with the proportion of 20:80 J: D these physical properties show a reduction of viscosity and density of vegetable oil. According the literature [21] the density shows 0.862 and the kinematic viscosity reduced to 6.932 which are more likely with diesel fuel at the temperature of 30^0C. From [10] it is discussed that the blends J:D 5:95, 10:90 and 20:80 their kinematic viscosity's are found to be around 3.94, 4.63 and 6.5 cSt at 40^0C respectively. And it is discussed that the less percentage of JVO and more Percentage of diesel gives more close property to Diesel fuel.

Some papers and [23] discussed that this vegetable oil (JVO) can be preheated to reduce the high viscosity of it before running on diesel engine. But [23] reported that a blend of vegetable oil with diesel with a proportion of J: D, 20:80 is with the acceptable limit of viscosity and conclude that it can be used as a diesel fuel without preheating it. It is also reported that increasing the content of petroleum diesel fuel can reduced the viscosity of the vegetable oil drastically from 52.76 cSt. For pure vegetable oil to 6.931cSt for 20:80 J: D blend.

2.6 Blending Techniques

Blending of two or more products by any method requires a recipe. A recipe is a formula or a set of instruction designed from the components of the blend and the percentages of each component. These calculations will determine meter and valve sizes and indicate any problematic flow control issues. The main objective of biofuel blending is to deliver an accurate and good and well blended fuel to do this there are four methods which are discussed below [45].

Parameters or characters of each products has their own effect on measurement while blending such as API tables, density, viscosity etc. This parameters has to be considered while blending two or more products in order to deliver a good blend [45]

Any product delivery, including straight product loading and any type of blending, requires that each component be capable of accurately flowing in a controlled mode throughout the delivery batch. This flow profile is most critical for ratio or hybrid blenders which is discussed below. If pumps and flow control valves are not sized properly, the results will be erratic operation and off specific blends. Complete pressure profile analysis should be done for all operating conditions to ensure accurate blending [45].

Products with similar characteristics such as density and viscosity will generally blend well. Products with different characteristics or those that when blended simply do not mix or stay mixed may dictate the method of blending or some other special consideration.

2.6.1 Splash Blending

This is the simplest method of blending which is two or more products can be blended. It only needs one storage tank or reservoir as a receiver and the other products could come with their storage tank. The process is simply loading the individual products into the container through dedicated product meters one after the other. The endothermic reaction between the products (like diesel and alcohol or others) occurs in the container [45].

2.6.2 Sequential Blending

This is also simple it is just loading the individual products through the same meter sequentially. The only difference between splash blending and sequential blending is in sequential blending the products are added to the reservoir with their proportion sequentially one to another. The endothermic reaction occurs in the container [45] figure 2.9 below shows sequential blending.

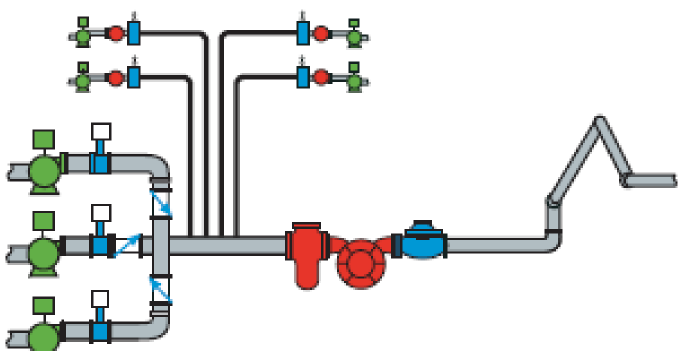


Figure 2. 9 Sequential blending process.

2.6.3 Ratio Blending

Ratio blending is defined as loading multiple products into a container at the same time as shown below on figure 2.10. Unlike sequential blending, ratio blending has a meter and control valve for each product. Because the products are blended at the same time, they will have a tendency to mix better than with sequential blending. Also, because all products are flowing during the entire batch, the blend should be on spec at any time during the batch; therefore, if a batch is aborted, the product loaded should be a deliverable product. For a sequential blend to be on spec, the entire batch must be completed [45].

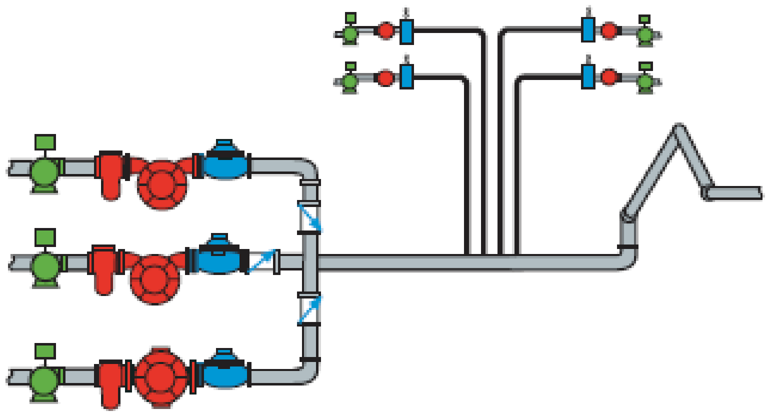


Figure 2. 10 Ratio blending process

2.6.4 Wild Stream or Side Stream Blending

More similar with ratio blending technique the process is metering the second product into the main first product line where the blending occurs directly upstream of the larger delivery meter shown below on figure 2.11. The endothermic reaction occurs prior to the delivery meter. It can also handle side stream blending where the smaller of the components are plumbed in upstream of the main product delivery meter [45].

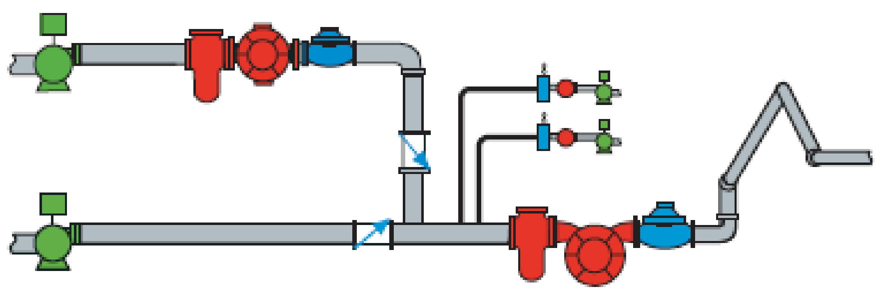


Figure 2. 11 Wild stream or side steam blending.

2.7 Properties causing Engine Wearing and Carbon Deposit

In [46] it discussed in detail the characteristic of a fuel from its crude source or from the refining process which it is produced is considered as a fuel property whereas a foreign matter introduced into the fuel due to refining, storage and transportation is considered as a contaminants. Some literatures [14], [17] and others classify as physical and chemical property whereas in [46] the property of the fuel classifies as characteristic property and contaminative properties. In [17] the properties of diesel fuel like water and sediment, Sulphur, carbon, hydrogen and carbon are discussed as physio-chemical property of a fuel with other flash and cloud point etc.

But in general the properties for a good diesel fuel are classified in three basic groups: satisfactory handling and storage, smooth and efficient burning and continued cleanliness during use. The properties which highly affects satisfactory handling and storage are the flash, fire, pour, cloud points and viscosity. The properties which contributes for smooth and efficient burning are volatility which related to emission of smoke and NOx and also related to carbon residue and flash point, Cetane number which determines the quality of ignition and finally heating value are the basic properties which are directly related to smooth and efficient burning of diesel fuel. In continued cleanliness during use is related to contaminate like sand, rest, water and sediments, Sulphur, carbon, hydrogen and other elements.

Diesel fuels are injected into the engine through precision pumps and fine injector nozzles. Dirt and water contamination must be avoided to protect these critical components. Specifications include tight limits on water and sediment, and most fuel stations also install final filters at the nozzles of fuel dock service pumps to protect against dirt picked up in the distribution system.

Viscosity: Viscosity is one of the most important property for a good diesel fuel. According to [11] , [20] and others viscosity can influences the spray pattern when the fuel is injected into the cylinder especially for high speed diesel engines. According to [46] low-speed marine engines can use higher-viscosity fuels than high-speed road-transport and generator engines, and still run without excessive smoking. This viscosity of a fuel can induce a high carbon deposit on the engine injection nozzle tips and in large it can cause wearing of engine components.

Carbon Residue: Deposit build-up in engines is also influenced by fuel quality. Fuels that leave a heavy carbon residue and contain excessive amounts of high boiling-point materials are prone to cause engine deposits [20].

Sulfur Content: During combustion, however, sulfur compounds burn to form acidic byproducts, SO_2 and SO_3, which form sulfates in the exhaust gas stream. Sulfates are part of a diesel engine's particulate emissions, therefore, controlling fuel sulfur level reduces the level of sulfate pollutants [20].

Depending on the crude source, sulfur compounds can also create corrosive sulfur oxides on combustion. These can cause high rates of engine wear and a rapid depletion of engine oil additives. Engine manufacturers often relate oil change intervals to the fuel sulfur content. According to Detroit Diesel, "diesel fuel sulfur content above 0.3% mass causes premature ring and cylinder liner wear and deposit formation."

Water Content: Diesel fuels also contain small amounts of water. Hydrocarbon type and bulk temperature control the amount of dissolved water that a fuel holds. Consider that water is much denser than fuel. When this encapsulated water hits a hot injector tip, it quickly expands into steam. Potentially, this can result in cracked, damaged, or blown-out fuel injectors are the potential problems [20].

CHAPTER THREE

MATERIALS AND METHODS

Using straight vegetable oil directly for diesel engine as a fuel causes carbon deposit and component wearing which can extremely harm the engine life. So to solve such problem some investigators work on modifying the engine, some others work on implementing preheating process prior to injection whereas others works on the fuel by producing biodiesel using transesterification and by blending vegetable oil with diesel. Blending mitigate or reduces the problem and also it avoids tedious work of engine redesign and an additional process of transesterification.

For this study a modern Robin DY-23 engine is used for experimenting and investigating the effects of B20 fuel which is a blend of Jatropha curcas L. oil and Diesel fuel. The study focuses on the carbon deposit formation and engine component wear. Studies show that carbon build up continues over time, resulting in higher engine maintenance costs, time and shorter engine life. The experiment to be conducted for this thesis is on a single cylinder engine for 75 hours working time at Adama science and technology university automotive work shop and with one diesel engine. The fuel is blend of Jatropha vegetable oil with diesel fuel with a percent of 20% by 80% respectively (B20).

3.1 Materials

The materials and devices those have been used in this experimental study starting from diesel fuel and vegetable oil storage tanks, blending devices and the engine and engine oil are listed on table 3.1 below and the general engine specification is listed on table 3.2.

Table 3. 1 List of materials

No.	Material (item)	Qty.	Remarks
1	Graduate Cylinders	2	Available in chemical department
2	Jatropha vegetable oil	5 liters	From local market
3	Diesel oil	25 liters	From local market
4	SAE 30 engine oil	4 liters	From local market
5	DY23-2D Engine	1	Engine available in workshop
6	Plastic Jar	2	From local market

Table 3. 2 General specification of the engine **[47]**.

Model	DY23-2D
Type	Air-Cooled. 4-cycle, Overhead Valve, Single vertical cylinder, Diesel engine
Bore	70 mm
Stroke	60 mm
Piston displacement	230cc
Compression ratio	21:1
Output HP/rpm	4.8/@3600rpm
Torque kg-m/rpm	1.07/@2200rpm
Rotation	Counterclockwise as viewed from PTO shaft side
Fuel	Automotive diesel fuel
Fuel Tank Capacity	3.2 liters
Combustion System	Direct injection type
Starting System	Recoil starter
Dry Weight	29 kg
Dimension L x W x H	329 x 357 x 402 mm

Figure 3. 1 Robin engine DY23-2D Engine.

The dismantling and assembling process is operated according to the manufacturers (Robin Industries) service and maintenance manual for the DY23-2D engine shown on figure 3.1 above. The wear measuring process and the limits under each components are referred from IS standard engine endurance test method the engine service and maintenance manual.

The equipment's are available in the work shop. Below Table 3.3 shows the list of tools used for disassembling of the engine but Table 3.5 shows the detailed equipment's and tools used for each parts of the engine.

Table 3. 3 List of equipment's used for dismantling and assembling the engine.

No.	Equipment name	Specification	Remarks
1	Open and Box end wrench	10 to 19 mm	
2	Socket wrench	set	
3	Hammer	2 pcs	small (Ball pin and plastic)
4	Screw drivers	2 pcs	Flat and Philips
5	Torque wrench	<50 Nm	
6	Digital Varner caliper	< 200mm	
7	Micrometers	0 – 100 mm	0-25,25-50,50-75&75-100
8	Bore and telescopic gauge	set	
9	Filler gauge	0 - 100 mm	

3.2 Methodology

To conduct this research the following (figure 3.2) methodology is used. It starts from the careful examination of the techniques of blending.

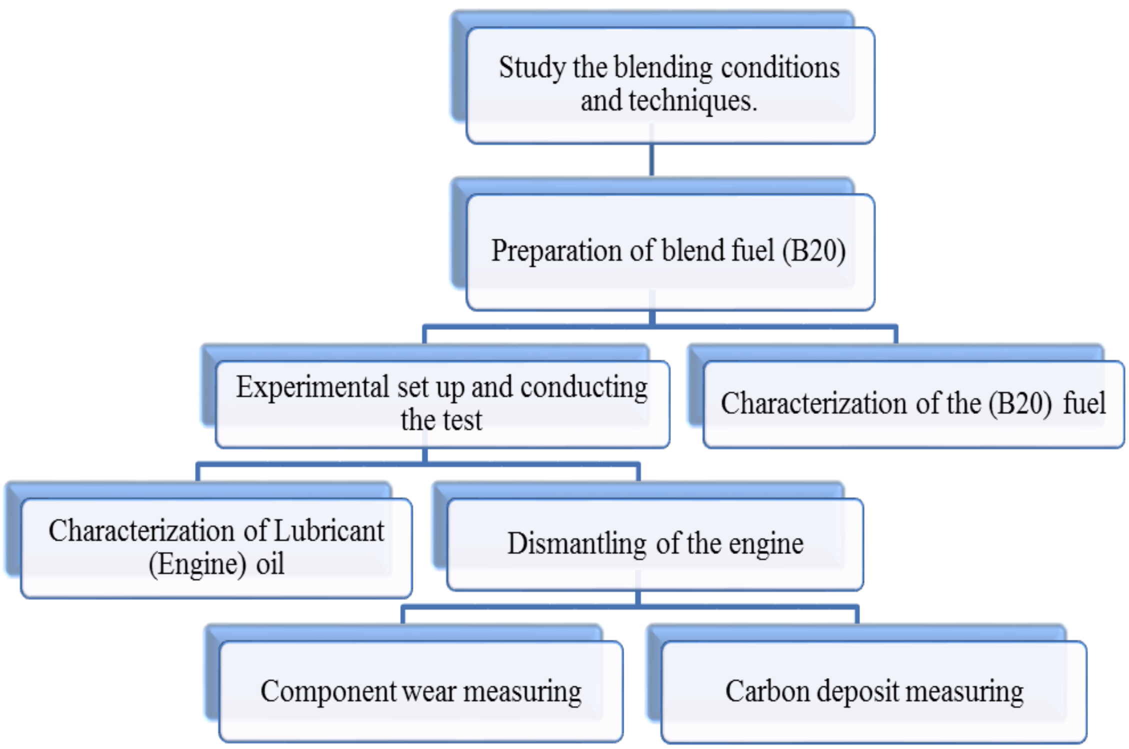


Figure 3. 2 Methodology used to conduct the research

3.2.1 Preparation of Jatropha and diesel fuel blend

This is the first step for this thesis work which is using diesel and vegetable oil preparing the fuel blend with a combination of 80% diesel and 20% vegetable oil (JVO). To prepare the blend a properly calibrated and clean volume measuring devices are used. On figure 3.3 below the graduated cylinders are used to measure diesel fuel (figure 3.3 a) and Jatropha vegetable oil (figure 3.3 b) in order to prepare the blended fuel.

Among the techniques of blending for this study splash blending which is very simple and cost effective mothed and the one which was very applicable for small scale blending's is used. As it is defined in the previous chapter under blending techniques splash blending is the simplest method. The process is adding or loading the products into the container after adding the first product with the appropriate ratio then the second product could be added or loaded with the required ratio or percent.

First 23 Liter diesel has been collected from local market with a plastic Jar of 25 lit capacity and then Jatropha oil is provided from the workshop with 5 lit capacity plastic Jar. So this Jatropha and diesel blend was prepared at Adama science and technology university chemical engineering department using a properly cleaned and dried graduating cylinder, and another 25 Liter plastic Jar has been used. So finally a total of 25 liter of 20% Jatropha and 80% diesel blend has been prepared.

(a) Diesel Fuel

(b) Jatropha vegetable oil

Figure 3. 3 Graduating cylinder for volume measuring

3.2.2 Characterizing the blended fuel (B20)

For this study the second important step is to identify or determine the very basic properties or characteristics of the fuel. For identification of some basic properties which are very contributing to wear of engine components and which affects the lubricant oil, we use standards. For example density, flash point, kinematic viscosity, cloud point, corrosiveness to copper, acid number and some others can be identified using ASTM standards and instruments. But for this paper the properties which are discussed below are characterized.

3.2.2.1 Density ASTM D-4052

Among the most important physical properties Density is a fundamental one that can be used in conjunction with other properties to characterize both the light and heavy fractions of petroleum and petroleum products. Determination of the density or relative density of the blended fuel can be done using Digital Density Meter shown on figure 3.4 below. The density of the B20 fuel of Jatropha vegetable oil and diesel at temperature of 15 and 20 °C has been determined.

Figure 3. 4 Digital density meter.

3.2.2.2 Flash Point ASTM D-93

A flash point is defined as the tendency of the fuel to form a flammable mixture with air and when it is in laboratory it is under controlled condition. One of the most important property which needs to be considered in safely storage and transporting property of the fuel. However, results of these test methods may be used as elements of a fire risk assessment which takes into account all of the factors which are pertinent to an assessment of the fire hazard of a particular end use. Flash point of the B20 is determined using Pensky-Martens Closed Cup (PMCC) as shown on figure 3.5 below.

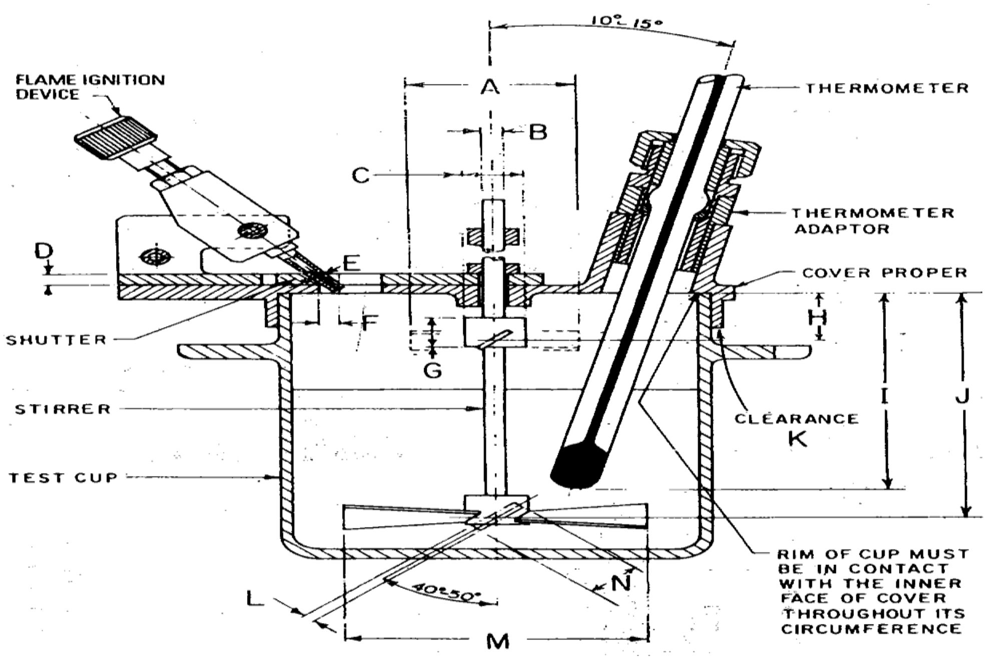


Figure 3. 5 Pensky-Martens Closed Cup

3.2.2.3 Kinematic Viscosity ASTM D-445

Viscosity is a measure of a fuel's resistance to flow when expressed in seconds of Redwood 1 (SR1) at 100 degrees Fahrenheit, it is the time it takes for a fixed amount of fuel to pass through an orifice of fixed size at 100 degrees Fahrenheit. The higher the viscosity, generally the higher the specific gravity. The viscosity of any petroleum oil increases when the oil is cooled and decreases when it is heated. For this reason, the viscosity value of an oil must always be accompanied by the temperature at which the viscosity was determined. The viscosity value by itself is meaningless. The kinematic viscosity is very important property for safe handling and smooth operation of an engine. For this paper the kinematic viscosity has been determine at 40^oC.

This test method specifies a procedure for the determination of the kinematic viscosity of liquid petroleum products, both transparent and opaque, by measuring the time for a volume of liquid to flow under gravity through a calibrated glass capillary viscometer shown on figure 3.6 below.

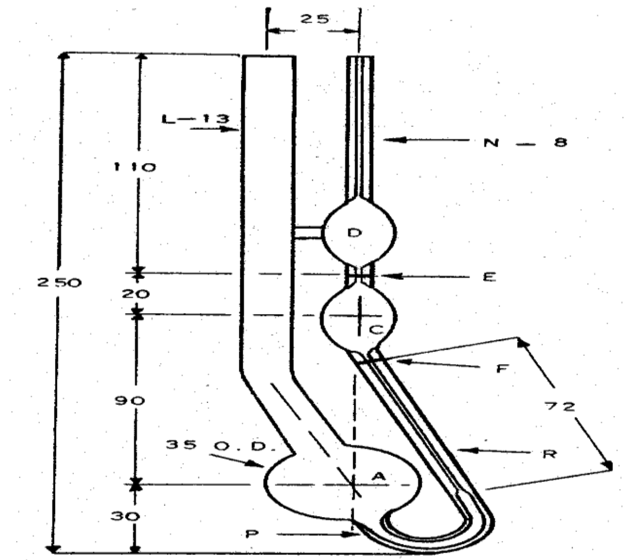


Figure 3. 6 Glass capillary tube in a SETA.KV-8 viscometer bath

3.2.2.4 Acid Number ASTM D-974

This test method covers the determination of acidic or basic constituents. It is applicable for the determination of acids or bases whose dissociation constants in water are larger than 10−9; extremely weak acids or bases whose dissociation constants are smaller than 10−9 do not interfere.

The nature of fatty acids and their contents in vegetable oils depend on the type of oil crop used. The nature of fatty acids largely determines their ability to burn correctly in an engine. Vaitilingom and Daho found that the unsaturation of triglycerides affected combustibility. The acidity in the blend fuel B20 was less than the straight vegetable oil.

3.2.2.5 Cloud Point ASTM D 2500

This test is performed on diesel fuels, fuel oils, and other petroleum oils that are transparent and have a cloud point below 120^{o}F. The cloud point is an indication of the behavior of an oil in certain lubricating devices.

Fuel oils and diesel fuels with high cloud point could clog fuel filters if a preheater is not used. Contamination with a heavier product can raise the cloud point. So ASTM D 2500 has been used to characterize the cloud point of B20. The test is conducted using the cloud point apparatus shown on figure 3.7 below.

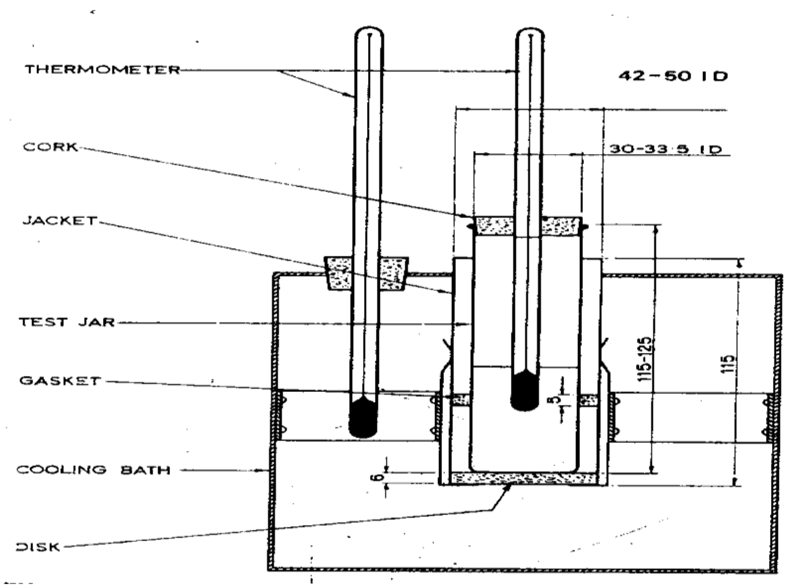


Figure 3. 7 ASTM Cloud point apparatus

3.2.2.6 Distillation

Distillation curves give the amount of a fuel sample that is evaporated in atmospheric pressure at each temperature when the temperature is increased gradually. Distillation characteristics illustrate how fuel is evaporated when it is sprayed into the combustion chamber of a diesel engine. Some fractions boiling at low temperatures are needed for engine start-up, while fractions boiling at too high temperatures may not combust completely forming engine deposits and increasing tailpipe emissions. ASTM distillation apparatus shown on figure 3.8 below is used to characterize the blended fuel distillation property.

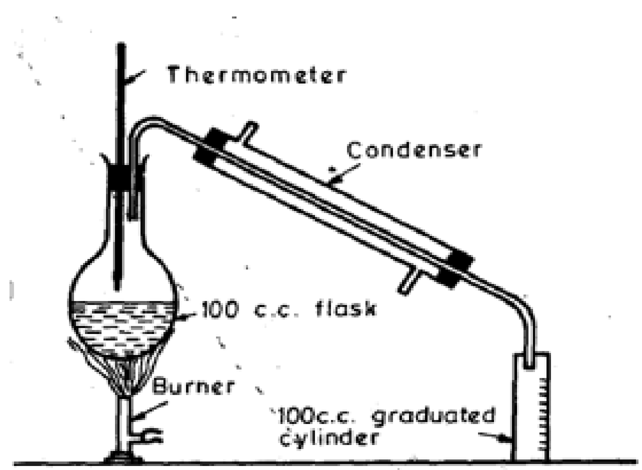


Figure 3. 8 ASTM distillation apparatus.

For determination of distillation ASTM D 86 is used the temperatures starting from initial boiling point up to final boiling point are registered. As distillation progresses, the composition of the sample changes. Some liquid residue may remain after the maximum temperature is reached. This portion of the fuel may not vaporize in service; it will remove the lubricant from the cylinder walls and contribute to crankcase oil dilution so this may cause wearing. A distillation curve for a result for distillation test of B20 is prepared.

3.2.3 Preparation of an experimental set up

A Robin DY23-2D engine is used to conduct the experiment and study the effect of the fuel on the engine parts. The experiment or the test was conducted for a period of 75 hours. Before starting the test, the engine was checked if it is working or not. Then we start the engine with diesel and run for 2-3 hours for warming up since the engine was idle for a year then adaptation of engine for the fuel was done for a half an hour. The figure 3.9 below shows all the engine checkup and preparation for test procedures made.

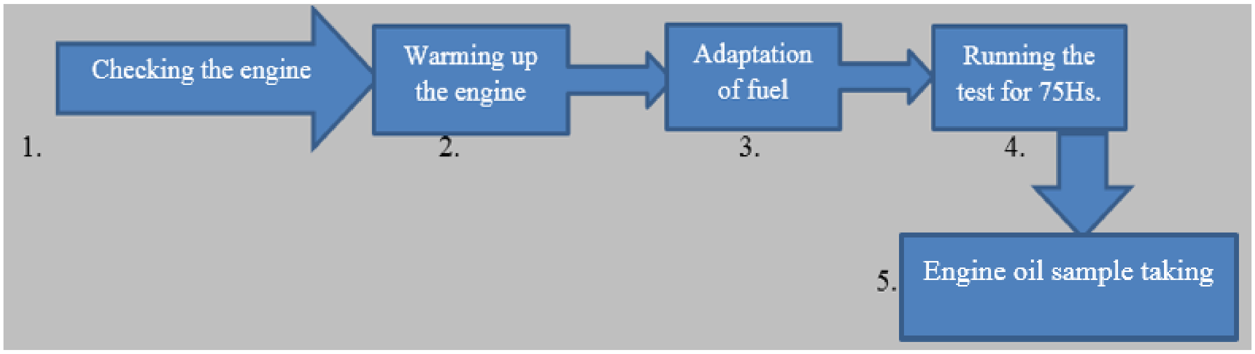


Figure 3. 9 Test preparation procedure.

All safety precaution like fueling and pre-operating are carefully taken care. The test was conducted 8 hours per day with two cycles or shifts 4 hours each and after the test starts daily inspection was done every day at the end of each 8 hours run. For the test Indian standard for testing engine (IS: 10000, Part IX, 1980) is used to run the engine (table 3.4). After warming up the engine and adapting the fuel which is B20 of Jatropha vegetable oil with diesel the test is conducted for a net of 75hrs until the sample of the lubricant oil has taken. It takes 9 and half days for a complete run.

Table 3. 4 Indian standard for testing engine (IS: 10000, Part IX, 1980.)

Throttle position	Running time
Fully opened	1hr.
Partial opened	1hr.
Fully opened	15min.
Idle	7.5min.
Fully opened	45min.
Partial opened	52.5min
Total engine running time per cycle	**4 hours**

Adama science and technology university automotive work shop specifically engine performance test room was used for every facility and engine maintenance. After the test completed using this engine performance room has been used to disassemble the engine and measuring the wearing of each components.

A periodic maintenance is used for the safe working of the engine due to its service manual the schedule used for the engine is tabulated below in table 3.5.

Table 3. 5 Engine maintenance schedule used for test.

Items to checked	Operation Hours			
	8 hours/each day	100 hours	500 hours	1000 hours
Check for oil and fuel leakage	x			
Check bolts and nuts for tightness.	x			
Check engine oil level	x			
Replace engine oil		x		
Check and adjust valve clearance.		x		
Discharge water from fuel filter.			x	
Replace or clean oil filter			x	x
Check nozzle and clean			x	
Check valve seat				x

3.2.4 Characterization of lubricant

From the manufacturers of the Robin engine DY23-2D manual, it is recommended that the lubricating oil type is SAE 30 and to fill it up to the upper level of the gauge. For this study after 75 hours of engine run sample oil is taken for examination of the oil characters. It is known that when we use a fuel which is driven from vegetables oil the engine oil will be affected too much. So the engine oil sample is taken at 25, 50 and 75 working hours but for this study only the 75hour sample is used to characterize the engine oil due to it cost of characterization is expensive.

The engine wear and dilution of engine oil has a direct relationship. When the engine runs a high temperature blow by flame burns the engine to some extent. The viscosity, density, flash point and other basic properties of the engine oil will be changed or altered due to that the engine components will wear easily. The ash content and gummy particulates on an engine oil will increase due to this the engine oil color and smoothness for operation will be affected. The total sum of these changes of the engine oil leading to the engine component wearing and engine failure in general.

The very basic properties use same ASTM standard method of test so for determination of density, kinematic viscosity, flash point, has used the same method as it listed above in 3.2.2.1, 3.2.2.2 and 3.2.2.3 respectively. The other two lubricant oil characterized properties in this thesis work are discussed below.

3.2.4.1 Determination of Sulfated Ash D 482

The determination of ash content is according to ASTM D-482. For diesel fuels or any other alternative fuel which is used for running an engine it is not desirable to have impurities and contaminates and the ash content must be minimum as much as possible. The process is oil sample contained in a suitable vessel was ignited and burned as shown in figure 3.10 below until only ash and carbon remain.

It is discussed in [48] that the carbonaceous residue was reduced to an ash by heating in a muffle furnace at 775°C, cooled and weighed. Knowledge of the amount of ash-forming material present in a product can provide information as to whether or not the product is suitable for use in a given application. Ash can result from oil or water-soluble metallic compounds or from extraneous solids such as dirt and rust.

Figure 3. 10 Determination of ash content [24].

3.2.4.2 Determination of Conradson carbon residue ASTM D 189

The standard for carbon residue test is ASTM D 189 using Conradson carbon residue equipment's shown on figure 3.11 below. The amount of carbon residue left after evaporation and pyrolysis of a used engine oil, and is intended to provide some indication of relative coke-forming propensities. This test method is generally applicable to relatively nonvolatile petroleum products which partially decompose on distillation at atmospheric pressure. The carbon residue is a measure of carbonaceous material left in an oil after all the volatile components are vaporized in the absence of air.

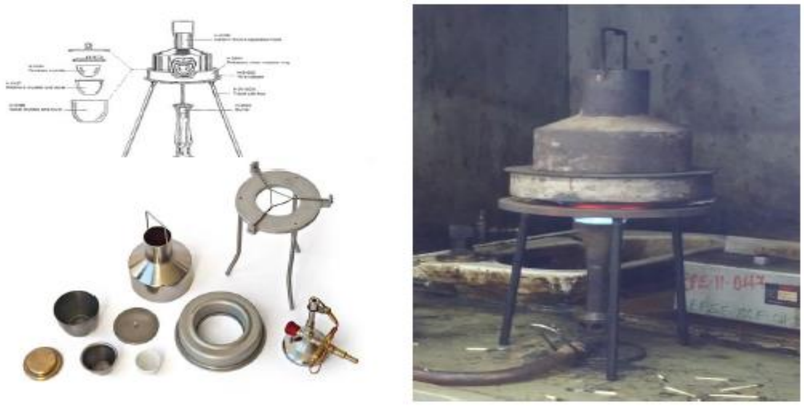


Figure 3. 11 Conoradson carbon residue determination **[49]**.

3.2.5 Dismantling and wear measuring of engine parts

To measure the physical wearing effects on the engine components due to the fuel used to run the engine the engine has to be dismantled. So that the components can be seen and be able to measure the wear. So, dismantling the engine has its own procedure. The following table 3.6 shows the detailed procedure to dismantle the engine with the proper equipment or tool for each step.

Table 3. 6 DY23 Engine Disassembling Procedure **[47]**.

Steps	Part to be removed	Procedure	Tool used
1	Engine oil	1) Oil was discharged from the crankcase by removing the drain plug on the side of the crankcase. 2) The oil gauges was removed to discharge oil quickly.	14 mm spanner
2	Fuel	1) The fuel was discharge from fuel tank by removing drain plug from fuel filter	10 mm spanner
3	Injection pipe	1) The two joint nuts at both ends of injection pipe were loosening first to remove it.	12 mm spanner
4	Air cleaner	1) The cleaner cover was removed first from the cleaner body. then, 2) Loosen the wing bolt to remove element. 3) Finally the cleaner body was removed from intake manifold. The flange bolts were 6Ø X 12 mm.....2pcs.	10 mm box wrench 12 mm box wrench
5	Recoil starter	2) The recoil starter was removed from Recoil starter blower housing. The flange bolts were 6Ø x 10 mm…….4pcs	10 mm spanner

6	Fuel tank	The step to remove the fuel tank was 1) Disconnecting fuel pipe from fuel tank. 2) Disconnecting fuel return pipe. 3) Disconnecting rubber pipe from the check valve. 4) Removing the fuel tank. 8Ø X 20mmbolt…………….. 1 pcs 8Ø X 30mmbolt…………….2pcs	12 mm spanner
7	Muffler	1) First muffler cover from muffler was removed by loosening the bolts with 8Ø X 20mm….1 pcs and 8Ø X 30mm...2pcs. 2) Then, remove the muffler by loosening the nut and spring washer respectively.	12 mm Box wrench
8	Fuel filter	1) The fuel filter was removed from the blower housing. By untightening the flange bolts of 6 Ø X 20 mm …..2pcs.	10 mm spanner
9	Blower housing	1) The blower housing was removed from the crankcase.by untightening the bolts and washer of 8 Ø X 20 mm...2pcs.	12 mm Box wrench
10	Rocker cover	1) The rocker cover was removed from the cylinder head by loosening the flange bolts of 6 Ø X 40 mm …..4pcs	10 mm Box wrench
11	Fuel injection nozzle.	1) The first step was removing the bracket nozzle; 2) The fuel injector from the cylinder head. During the removal of the injector nozzle care has taken not to lose the gasket at the bottom end of the nozzle.	10 mm box wrench
12	Rocker arm	1) Loosening the adjusting bolts on the rocker arms. 2) Pushing the rocker shaft out from the cylinder head to remove the rocker arms. 3) Removing push rods. The pushrods and rocker arm were marked to easily identify the intake and exhaust.	10 mm spanner
13	Cylinder head	1) The cylinder head was removed from the cylinder by removing the flange nuts of 8 Ø …..4pcs while giving taking care for spacers.	12 mm spanner
14	Main bearing cover	1) First the bolts joining the main bearing cover and crankcase 8Ø X 35 mm….11 and 8Ø X 40 mm….1 were loosening. 2) Then, lightly tap the cover with aplastic hammer to remove from the crankcase.	12 mm Box wrench Plastic hammer
15	Connecting rod	1) The connected rod was removed by loosening the connecting rod bolts and removing the large end cap.	10 mm Box wrench

		2) Then, by pushing the connecting rod up until it completely out from the cylinder while the crankshaft is turned to top dead center.	
16	Piston and piston pin	1) The removal of the piston was started by removing the two clips at both ends of piston pin and 2) Pushing the piston pin out from the piston which is used to remove the piston from the connecting rod. 3) The piston rings also removed from the piston by spreading their open ends.	
17	Crankshaft	1) Lightly tap the crankshaft at the flywheel side using a plastic hammer to remove it from the crankshaft.	
18	Intake and Exhaust valves	1) Press the valve springs and remove the retainer lock from the valve stem. 2) Remove the valve from cylinder head. Marking of retainers has been made to identify the intake and exhaust.	

The tools used for disassembling of the engine which are tabulated on table 3.3 on page 24 of this paper are shown in the following figure 3.12 below.

Figure 3. 12 Tools used for dismantling Robin DY-23 engine.

3.2.5.1 Wear measuring of engine components

The wear of engine components could be measured using different tools (figure 3.13) according to the Indian standard (IS: 10000) Part V Preparation for Tests and Measurements for Wear. The wear is caused due to prolonged engine operation and the limits are according to the manufacturers of the engine. It is clear that the fuel used to run the engine has determines the engine wear and life span due to its physio-chemical characteristics.

Figure 3. 13 Tools used for wear measures of the components.

The appropriate device for the appropriate engine part which must be used are tabulated in the following table 3.7 and the procedures for measuring is according to the Indian standard.

Table 3. 7 Appropriate devices used for wear measurement.

S.NO	Engine part	Appropriate device
1	Cylinder bore	Bore gauge and Micrometer
2	Connecting Rod Bearing	Telescopic gauge and Micrometer
3	Gudgeon Pin, Pin Bore and Small End Bush	Telescopic gauge and Micrometer
4	Piston	Micrometer
5	Piston rings	Micrometer, feeler gauge and venire caliper
6	Inlet and exhaust valves	Micrometer and venire caliper
7	Rocker arm	Telescopic gauge and Micrometer

3.2.6 Carbon deposit evaluation

The very focusing area for this thesis work is to determine the carbon deposit and the components which carbon deposit can be seen are piston head, cylinder head, injector tips, piston side, exhaust and intake ports and intake and exhaust valves. The amount of carbon deposited on these components can be measured by gram using the following procedure.

1. First after disassembling the engine these components could be left to dry then
2. The components weight is measured using the digital gram measuring device.
3. After the measured weight has been registered the components has to be cleaned properly and the Carbon deposit has to be removed from the components carefully.
4. Then the weight has to be measured again then

5. It is assumed that the weight difference in gram is the amount of carbon deposit found at that component the total can be the total sum of the weight difference found on the components.
6. For a better conclusion the carbon deposit which is removed carefully has measured for a better result of a measured weight of the carbon deposit.

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 Fuel characterization results

The property of the fuel B20 were characterized from Ethiopian Petroleum Supply Enterprise and tabulated below in Table 4.1. Mainly diesel standard are used to evaluate some characteristics of this Jatropha and diesel blend B20. There are standard limits which the company (Ethiopian Petroleum Supply Enterprise) use to compare if the fuel is suitable for diesel engine or not. However, the most important properties of the fuel used in the study were characterized by ASTM standard test methods and the results are given below.

Table 4. 1 Fuel Characteristic property of B20

<table>
<tr><th>S.no.</th><th colspan="2">Property Characterized</th><th>ASTM Test method</th><th>Test Result Obtained</th></tr>
<tr><td>1</td><td colspan="2">Kinematic Viscosity@40^{0}C.</td><td>D445</td><td>5.83</td></tr>
<tr><td rowspan="2">2</td><td colspan="2">Density @15^{o}C,g/ml</td><td>D 4052</td><td>0.8660</td></tr>
<tr><td colspan="2">Density@20^{o}C,g/ml</td><td>D 4052</td><td>0.8623</td></tr>
<tr><td>3</td><td colspan="2">Flash Point(PMCC),^{o}C</td><td>D 93</td><td>>92</td></tr>
<tr><td>4</td><td colspan="2">Total Acidity, mgKOH/g</td><td>D 974</td><td>1.12</td></tr>
<tr><td>5</td><td colspan="2">Cloud point, ^{o}C</td><td>D 2500</td><td>+2</td></tr>
<tr><td rowspan="7">6</td><td rowspan="7">Distillation</td><td>IBP,^{o}C</td><td>D 86</td><td>206.0</td></tr>
<tr><td>10%volume,recovered,^{o}C</td><td>D 86</td><td>241.5</td></tr>
<tr><td>40%volume,recovered,^{o}C</td><td>D 86</td><td>302.0</td></tr>
<tr><td>50%volume,recovered,^{o}C</td><td>D 86</td><td>315.5</td></tr>
<tr><td>90%volume,recovered,^{o}C</td><td>D 86</td><td>356.0</td></tr>
<tr><td>95%volume,recovered,^{o}C</td><td>D 86</td><td>359.0</td></tr>
<tr><td>IBP, ^{o}C, Max.</td><td>D 86</td><td>361.0</td></tr>
</table>

The properties of the fuel which are tabulated on table 4.1 are not only the cause of wearing and carbon deposit formation inside the combustion chamber. In this thesis some of the diesel fuel properties are not characterized due to the expensiveness of the test which could be provided at Ethiopian petroleum Supply Enterprise. But for this research work the properties has been selected due to their tendency of causing the effects.

According the result the kinematic viscosity for Jatropha curcas oil and diesel fuel blend of 20/80 respectively in percent, is 5.83 at 40^{o}C but the limit for diesel fuel is between 1.9 and 5.5. Due to this higher kinematic viscosity of the fuel the engine may be affected by the flow pattern of the fuel through the injectors and the atomization process of the fuel will be decreased. If there is a poor atomization of fuel an efficient burning of fuel couldn’t be achieved. When we compare it with the burning of pure vegetable oil this B20 is very much efficient but when we compare it with diesel fuel it gives as a relatively less burning. According to the result obtained from [50] the kinematic viscosity of the pure Jatropha curcas oil is 34.48 at 40°C and clearly 83.09% of kinematic viscosity reduction has been obtained when it is blended with diesel fuel at a percent of 20%(B20).

The most effective way of reducing the density of vegetable oil is blending them with diesel fuel and adding some additives as we can see from table 4.1 the density of the B20 of Jatropha and diesel fuel is 0.8660 and 0.8623 at 15°C and 20°C respectively. This indicates that a very valuable reduction of density has been seen when we compare it from straight Jatropha curcas oil. Some researcher discussed that the density of Jatropha vegetable oil is above 46 at 30°C and from [50] it is discussed that the density of Jatropha curcas oil which is similar with oil used for this thesis is 0.9193 and 0.9162 at 15°C and 20°C respectively.

The result indicates a reduction of density when it is blended with diesel fuel. So the effects due to density of the fuel should minimize. A good burning of B20 is shown even while the experiment conducted the engine shows a better operation time than that of the experiment conducted by [24]. The difficulties of operation due to density has been clearly avoided so that the engine used for running B20 has worked for a complete test of 75 hours.

The cloud and flash point of B20 lies between the acceptable limit of diesel fuel which gives as similar effect on the engine. But when we observe the total acidity it is greater than that of the diesel fuel acceptable limit. Depending on the crude source or the vegetable oil source the acidity of the fuel can also create corrosive acidic oxides on combustion. These can cause high rates of engine wear and a rapid depletion of engine oil additives. Engine manufacturers often relate oil change intervals to the fuel sulfur content. According to Detroit Diesel, "diesel fuel sulfur content above 0.3% mass causes premature ring and cylinder liner wear and deposit formation."

The distillation curve for the characterized fuel (B20) is shown below on figure 4.1. The distillation curve is an indication of the combustion characteristics of the fuel and also serves as a measure of the level of purity of the fuel. The higher initial boiling temperatures are an indication of the higher flash point of the vegetable oils as compared to diesel. When the blend B20 of Jatropha oil and with diesel fuel distillation temperature is compared with diesel fuel it shows that it close to the diesel fuel standard for example when 90% of B20 is 356°C which is between the range of diesel temperature which is sate to be in the range of 282-362°C. And also the final boiling point of diesel fuel has to be 390°C and when we observe the final boiling point of this B20 fuel is found to be 361°C.

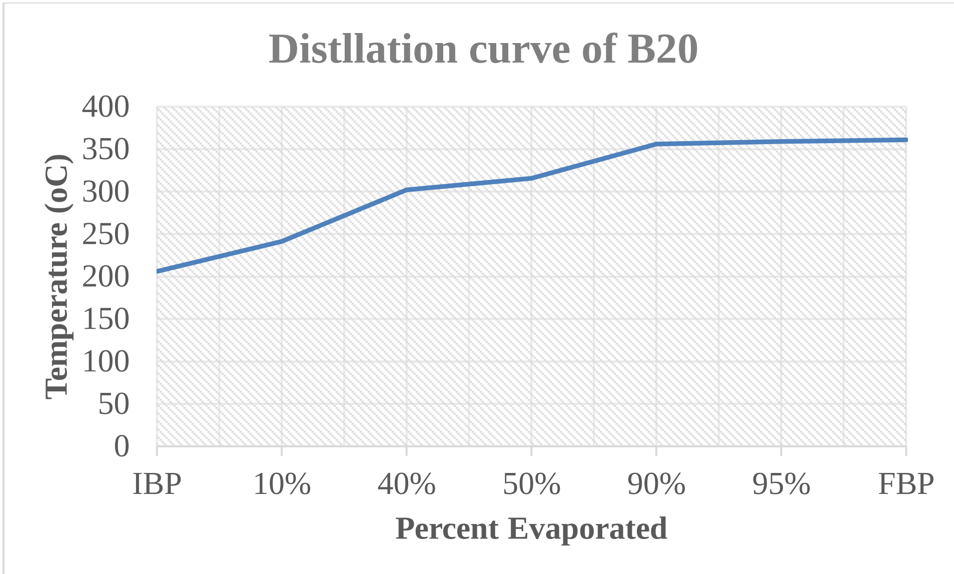


Figure 4. 1 Distillation diagram of B20.

4.2 Characterization of lubricant oil

The study under this thesis is to study the effects of the fuel used (B20 of Jatropha curcas oil with diesel fuel) for diesel engine on engine lubricating oil. So some of the engine oil properties has been characterized using ASTM standard.

Table 4. 2 Lubricant property after 75 hour run.

S.No	Property	ASTM Test method	Test Result Obtained
1	Density @15ºC,g/ml	D 4052	0.8927
	Density@20ºC,g/ml	D 4052	0.8898
2	Flash Point(PMCC),ºC	D 93	>100
3	Kinematic Viscosity@40^{0}C.	D 445	5.83
4	Conradson carbon residue, %wt.	D 189	1.50
5	Ash Content, %wt.	D 482	0.98

The main reason for the change of the lubricant oil properties is dilution of the fuel used in the engine and the leaking of this unburned fuel through the cylinder wall. For safe working of the engine the oil should be clean and stable. But using straight vegetable oil or any other alternative fuel increases the dilution and affects the engine oil more than diesel fuel.

The properties of lubricant oil SAE 30 after 75 hours of running is tabulated above on table 4.2 and some major changes are observed. According to the study the density of the engine oil after the test is conducted shows a little increment due to dilution of the fuel (B20) used and the wear debris contamination. The carbonaceous deposits and the ash related issues may increase the density of the lubricant oil. Since the lubricant oil is supposed to clean the engine moving parts inside the cylinder and housing of the engine it could contain so many contaminations like particulate matters caused by dilution and engine part wear. The SAE 30 oil density at 20°C is found to be around 0.8891 but after the test it is found that 0.8898 g/ml. when this result is compared with straight vegetable oil which is found to be 0.8999g/ml from a study done by Mr. Anwar. This effect also has a relation with the density of the fuel used.

Kinematic viscosity, which is the important property of the lubricant oil has changed from 110 cSt to 5.83 according to the characterization of the Ethiopian petroleum supply enterprise. For a change encountered in viscosity the working condition, environmental weather condition and dilution of the unburned fuel plays a huge role.

The dilution of unburned fuel affects the flash point value of the engine oil. As the flash point registered for the fuel used (B20) is less than that of the SVO and slightly higher than that of diesel fuel. The flash point for the B20 of Jatropha curcas oil and diesel fuel is >92°C the dilution effect on engine oil may be higher than that of SVO of Jatropha seed which is found to be >207°C. So the flash point for the engine lubricant oil after the engine has run for 75 hour using B20 is found to be >100°C.

The tendency of the engine oil SAE 30 to cause carbon residue is around 1.50 and after the test is conducted it is found to show no change which means the fuel used B20 have a low tendency of making carbon residue. But when using straight vegetable oil the tendency of the engine oil to make carbon residue is found to be more than 2. The tendency of causing ash is found to be minimized and it is around 0.98 %wt for B20 and around 1.18%wt for SVO of Jatropha curcas oil.

4.3 Wear measurements after the test

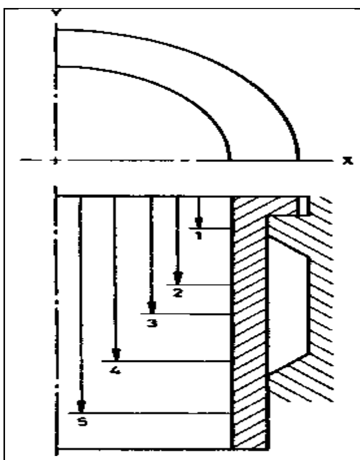
It is discussed that wear of various moving parts take place due to prolonged engine operation and the type of fuel used. The measuring procedure for wear of engine parts is according to the standard of IS: 10000 part V. To make a comparison of wear induced while using B20 and diesel fuel the engine must be new and similar. But the engine used in this thesis work was used to run a diesel fuel so it is not appropriate to compare the wear of the components with the previous works. However it is good to know the amount of the wear measures to judge whether the engine will work or not. If the wears are under the limit sated by the manufacturers, it will work when we assembled back.

4.3.1 Cylinder bore

Wearing effects of this B20 fuel has been measured and tabulated below on table 4.3 as it can be observed the maximum limit is 70.25mm. A little increment on the wear is shown (figure 4.2) but since it is below the maximum limit the engine will face no failure.

Figure 4. 2 Measuring of cylinder bore wear [24].

Table 4. 3 Cylinder bore wear measurement of the blended engine

<table>
<tr><td rowspan="7"></td><td colspan="5">Cylinder bore measurement before blend fuel run (x-direction)</td><td colspan="5">After the blended fuel test</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td>70</td><td>70</td><td>70</td><td>70</td><td>70</td><td>70.03</td><td>70.04</td><td>70.02</td><td>70.01</td><td>70.01</td></tr>
<tr><td colspan="5">Cylinder bore measurement before blend fuel test (Y-direction)</td><td colspan="5">After the blend fuel test</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td>70.01</td><td>70</td><td>70</td><td>70</td><td>70</td><td>70.02</td><td>70.01</td><td>70.03</td><td>70.02</td><td>70.01</td></tr>
<tr><td colspan="5">Max. limit = 70.25mm</td><td colspan="5">Note: - all dimension are in mm.</td></tr>
</table>

Wear of cylinder bore is caused by the up and down motion of the piston since they are in contact with piston and piston ring. If the unburned fuels cause carbonaceous particulate matters and the abrasiveness of these carbonaceous deposits and the friction induced between cylinder wall and piston skirt and piston rings cylinder wall or we call it cylinder bore may be scratched and wear when the engine runs for prolonged period.

When we see from table 4.3 above all measured values of the cylinder bore wear measures are under the limit stated by the manufacturers while the engine runs using B20 for 75 hour and wear is tabulated in percent on table 4.4 below. This shows that the fuel can be used for running this kind of small scale engines. The surface condition on the top of the cylinder bore is smooth.

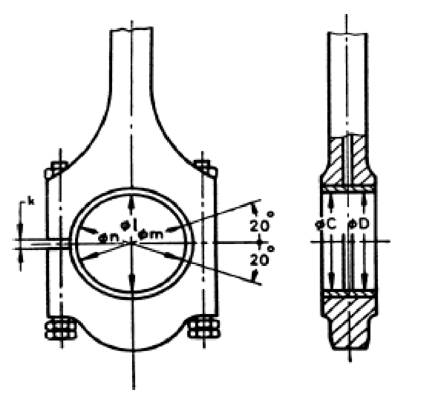
Table 4. 4 Wear analysis for the cylinder bore in percent

Direction	1		2		3		4		5	
	Wear (mm)	%	Wear (mm)	%	Wear (mm)	%	Wear (mm)	%	Wear (mm)	%
X	0.03	12	0.04	16	0.02	8	0.01	4	0.01	4
Y	0.02	8	0.01	4	0.03	12	0.02	8	0.01	4

4.3.2 Connecting rod bearing bore

The failure of an engine is mainly related or accumulated on the fast moving parts of the engine. So connecting rod bearings, rocker arms, pins and connecting rod of small end of the engine are supposed to wear due to their relative motion between each other.

Table 4. 5 Wear of connecting rod bearing bore



Measuring points		Dimensions	
		Before blend fuel test	After blend fuel test
C	l	33.06	33.08
	m	33.07	33.09
	n	33.06	33.07
D	l	33.07	33.09
	m	33.06	33.08
	n	33.06	33.07
Max. limit = 33.20 Note:- All measures are in mm.			

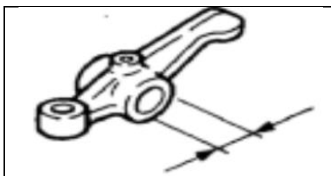
The result shown on table 4.5 which is the measures of wear on connecting rod bearing bore are totally under the limit stated on manufactures manual which 33.20mm and the percentage is listed below on table 4.6.

Table 4. 6 Wear analysis in percent

Measuring point		Wear measured (mm)	Percent of wear (%)
C	l	0.02	12.5
	m	0.03	18.75
	n	0.01	6.25
D	l	0.03	18.75
	m	0.02	12.5
	n	0.01	6.25

4.3.3 Rocker arm

Table 4. 7 Wear of rocker arm

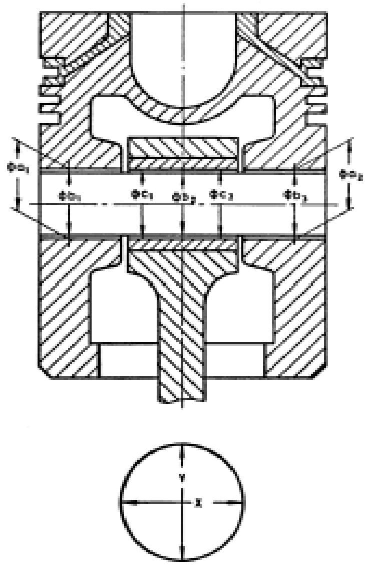


IN/EX	Before the test	After the test
Intake	12.01	12.03
Exhaust	12	12.01
Max. limit=12.07		

The maximum limit for the rocker arms of inlet and exhaust valves is 12.07 from the manufacturer's service manual which is shown on table 4.7. Using the limit the wear measured value according to the standard in percent are 42.85% on intake and 14.28% wear is measured on exhaust rocker arm.

4.3.4 Gudgeon, Pin and Small end bush of connecting rod

Table 4. 8 Wear measured of Gudgeon, pin and small end bush of connecting rod

<table>
<tr><td rowspan="6"></td><td colspan="11">After endurance test using B20(Jatropha oil with diesel fuel blend)</td></tr>
<tr><td colspan="3">Gudgeon pin bore(in piston)</td><td colspan="3">Gudgeon pin diameter</td><td colspan="2">Clearance between</td><td colspan="2">Small end bush</td><td colspan="2">Clearance between</td></tr>
<tr><td></td><td>a1</td><td>a2</td><td>b1</td><td>b2</td><td>b3</td><td>a1&b2</td><td>a2&b3</td><td>c1</td><td>c2</td><td>b2&c1</td><td>b2&c2</td></tr>
<tr><td>X (mm)</td><td>18.012</td><td>18.013</td><td>18.002</td><td>18.003</td><td>18.002</td><td>0.009</td><td>0.010</td><td>18.015</td><td>18.015</td><td>0.012</td><td>0.012</td></tr>
<tr><td>Y (mm)</td><td>18.009</td><td>18.009</td><td>18.003</td><td>18.003</td><td>18.003</td><td>0.006</td><td>0.006</td><td>18.018</td><td>18.018</td><td>0.015</td><td>0.015</td></tr>
<tr><td colspan="6">Max limit:
a = 0.029, b=0.02 and
C=0.021</td><td colspan="6">Max limit between a, b and c
a&b = 0.049(100% wear)
b&c = 0.041 (100% wear)</td></tr>
</table>

Note: - all dimensions are in mm.

The limiting value of wear measure is listed above in table 4.8 and the percentage of wear is tabulated on table 4.9 below.

Table 4. 9 Wear of Gudgeon, pin and small end bush of connecting rod in percent

Direction	a1	a2	b1	b2	b3	a1&b1	a2&b3	c1	c2	b2&c1	b2&c2
X	41.37	44.82	10	15	10	18	20	71	71	29.26	29.26
Y	31	31	15	15	15	12	12	85	85	36.58	36.58

4.3.5 Piston

Table 4. 10 Wear measures in piston

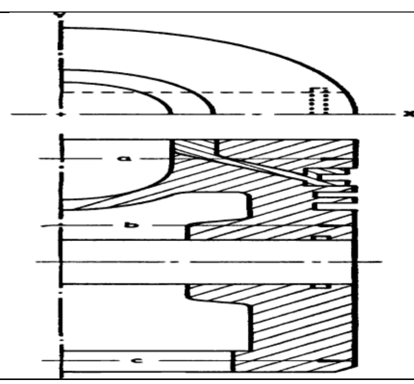
<table>
<tr><td rowspan="8"></td><td colspan="3">After endurance
test using B20</td></tr>
<tr><td>Position</td><td>$\emptyset X$</td><td>$\emptyset Y$</td></tr>
<tr><td>a</td><td>69.952</td><td>69.961</td></tr>
<tr><td>b</td><td>69.943</td><td>69.961</td></tr>
<tr><td>c</td><td>-------</td><td>--------</td></tr>
<tr><td rowspan="3">Maximum limit = 69.871</td><td colspan="2">Surface condition</td></tr>
<tr><td>Top</td><td>Smooth</td></tr>
<tr><td>Skirt</td><td>Smooth</td></tr>
</table>

Table 4. 11 Wear measured on piston in percent

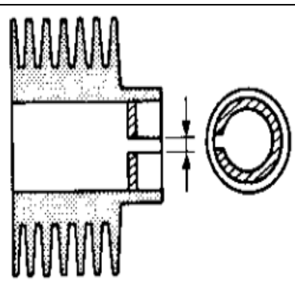
Position	$\emptyset X$		$\emptyset Y$	
	Wear (mm)	Percent (%)	Wear (mm)	Percent (%)
A	0.028	25.68	0.019	17.43
B	0.037	33.94	0.019	17.43
c	____	____	_____	_____

The above table 4.10 and table 4.11 are the wear measured and wear percentage on piston respectively. The top surface of the piston is covered with deposit formation which needs to be clean and less amount of carbon deposit on skirt of the piston head. Unless the measuring excides the maximum limit the piston would work safely. The carbon deposit formed on piston head or cylinder head and others should be removed using a proper material and chemical in order to minimize the damage on the surfaces of the engine parts.

4.3.6 Piston ring

For piston ring all dimension are under the limit but the top piston ring is failed to move due to sticking. The carbon deposit caused by B20 is comparatively less than the engine run with straight vegetable oil. But with this amount of carbon deposit the top piston ring sticking happened.

Table 4. 12 Data measured from piston rings end gap

<table>
<tr><td rowspan="8"></td><td>Position</td><td colspan="2">Before test</td><td>After test</td></tr>
<tr><td>Top</td><td colspan="2">0.3</td><td>0.42</td></tr>
<tr><td>Middle</td><td colspan="2">0.45</td><td>0.51</td></tr>
<tr><td>Oil ring</td><td colspan="2">0.3</td><td>0.37</td></tr>
<tr><td rowspan="4">Max limit =1.0mm</td><td colspan="3">Surface condition</td></tr>
<tr><td>Top</td><td colspan="2">More carbon deposit and rough</td></tr>
<tr><td>Middle</td><td colspan="2">Less carbon deposit, smooth</td></tr>
<tr><td>Oil ring</td><td colspan="2">Smooth</td></tr>
</table>

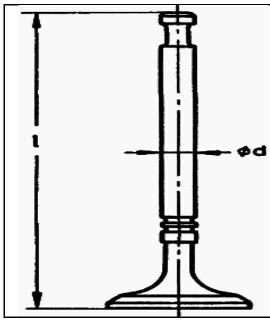
The limit for the piston ring gap is 1.0mm and the measured values of the gap after the test is conducted are listed on table 4.12 above. The percentage expression of the piston ring end gap after the test has conducted after 75 hours is given below on table 4.13.

Table 4. 13 The piston rings end gap measures in percent

Position	End gap measured (mm)	Percent to the limit (%)
Top ring	0.12	17.14
Middle ring	0.10	16.66
Oil ring	0.07	10

4.3.7 Inlet and exhaust valve

Table 4. 14 Wear measured on intake and exhaust valve

	Measured values			
	Measuring point		Before the test	After the test
	Steam diameter	Inlet	5.42	5.42
		Exhaust	5.42	5.42
	Length l	Inlet	71	71
		Exhaust	71	71
	Maximum limit for steam diameter = 5.35			

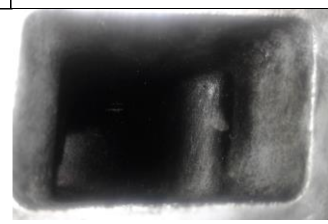
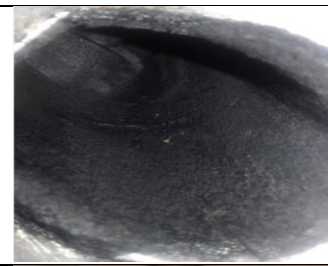
The above table 4.14 is wear measured on the intake and exhaust valve and the surface conditions for inlet valve is smooth and less carbon deposit found on its length side. But for the surface of exhaust valve more carbon deposit and rough surface is observed. Whereas the steam diameter side of both valves are smooth and less carbon deposit is observed.

4.4 Carbon deposit formed on engine components

Deposits in the combustion chamber of a diesel engine may be classified based on their location into: injector tips, piston crown, intake/exhaust valves, cylinder head and piston grooves. The carbon deposit mainly occurred on the engine components which is basically found at the clearance volume and carbon deposit could be observed as tabulated below on table 4.15.

Table 4. 15 Carbon deposit formation comparison table.

Engine Part	Diesel fueled engine	JSVO fueled engine	JSVO/D blend fueled engine (B20 blend)
1. Piston side			
2. Piston head			

3. Injecto r tips			
4. Cylinder head			
5. Intake port			
6. exhaust port			
7. Intake valves			
8. Exhaust valve			

As it can be observed from the pictures shown on the table the amount of carbon deposit is for the blended fuel is found between the diesel and the JSVO fueled engines. From the observation of the components for each test we can say that using SVO can accumulate more carbon than the pure diesel and B20 blend fuel of Jatropha so it is known that the amount of carbon deposit found could an indication for the fuel that determine the engine life if there is high amount of carbon found the more it become abrasive for the engine components. If there is any abrasive thing inside the combustion chamber the wearing rate of the components will increase and the wear shorten the engine life.

The amount of carbon found was measured after it is removed from the components carefully. The measuring was done at chemical department using digital weight measuring device. The weight was measured and graphed by classifying in to two parts the first part is carbon deposit on the piston head this include only the piston head and the piston side carbon deposit. The second is carbon deposit on cylinder head and its components like intake and exhaust manholes, valves and injector nozzle.

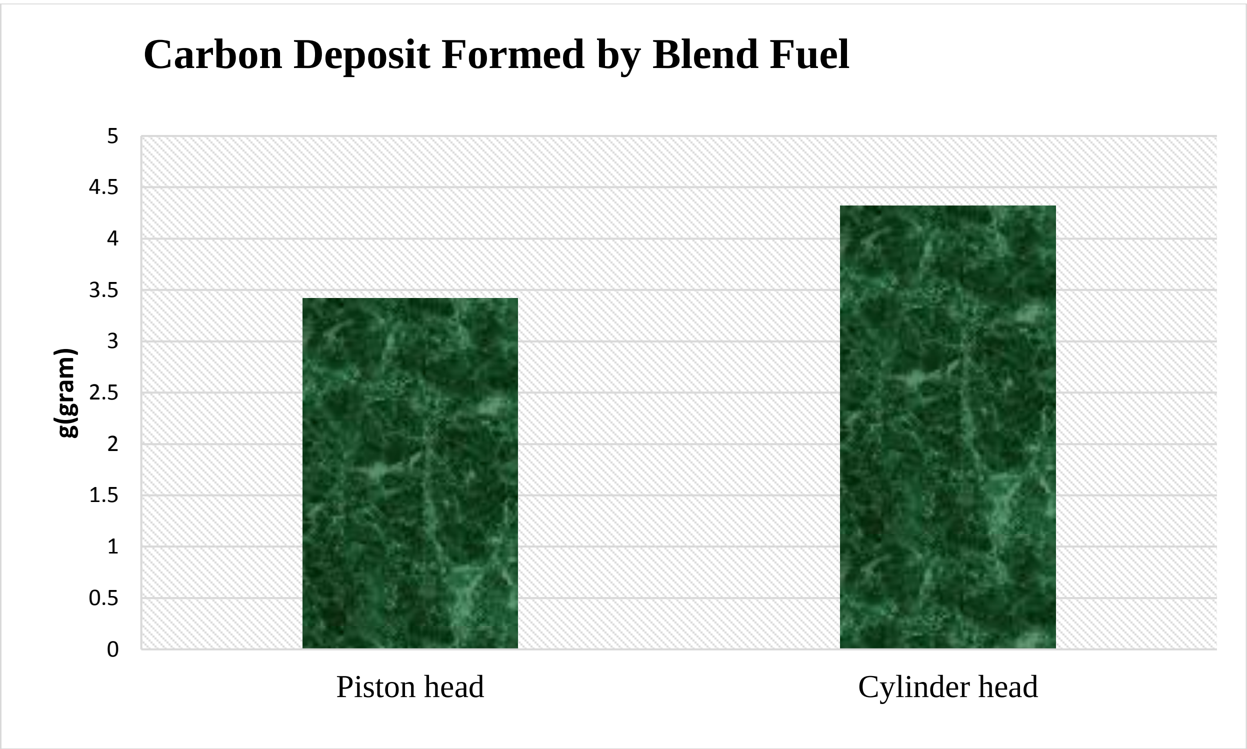


Figure 4. 3 Carbon Deposit formed by blended fuel on piston head and cylinder head.

The carbon deposit found on piston head is measured in gram and it is 3.42g and on the cylinder head 4.32 g so the total weight for carbon deposit is 7.74g. Carbon deposit is mainly caused by the viscosity, sulfur content, carbon residue, and water contamination or water content of the fuel used.

When the test is conducted it is tried to follow the standard testing speed changes as much as possible. The engine used for this test is designed for pump application so it is stationary engine and the speed of operation for the specified application needs to be changed and regulated as it is wanted. Conducting the test with different speed is to pretend that the engine is working at the real environment but one has to study the test with a real load.

When carbon deposit if formed, the engine oil changes its color and the sound of the engine makes a little change. But to minimize the carbon deposit the properties of the fuel has to be modified with a series of studies. The problem with straight vegetable oils is causing high carbon deposit but when they are modified they become more suitable and compatible with the engine but still they need modification. B20 of Jatropha oil with diesel fuel gives relatively less carbon deposit than straight Jatropha oil. However, B20 itself causes higher carbon deposit as we compare with diesel fuel. Further modification could be done to minimize the carbon deposit formation caused by B20 by preheating.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

To summarize the work done for this paper, a blend of 20 by 80% of Jatropha curcas oil and diesel fuel respectively has been made. The property of the fuel B20 were characterized and after the test is conducted the lubricant oil property were characterized. Then after the engine component wear and carbon deposit formed are measured.

As it is observed one important conclusion that can be drawn from the work done earlier is that the vegetables oils can't be used directly in the diesel engine. Several problems crop up if unmodified fuel is used and viscosity was the major factor. It has been found that blending vegetable oil with diesel could be an appropriate way to reduce the viscosity of vegetable oils and to make them fit for their use in the present diesel engines without any modification and also without any other extra process of transesterification.

Since diesel fuels are injected into the engine through precision pumps and fine injector nozzles, dirt and water contamination must be avoided to protect these critical components. The property of the fuel used is the main constraint for injector and other problems.

Generally the properties for a good diesel fuel are classified under three basic groups: satisfactory handling and storage, smooth and efficient burning and continued cleanliness during use. The properties which included in handling and storage are the flash, fire, pour, cloud points and viscosity. The properties which included in smooth and efficient burning are volatility which related to emission of smoke and NOx and also related to carbon residue and flash point, Cetane number which determines the quality of ignition and finally heating value are the basic properties. In cleanliness during use means it is related to contaminate like sand, rust, water and sediments, Sulphur, carbon, hydrogen and other elements. From these general properties and the research work the following conclusions are drawn;

1. The total sum of the properties mentioned above can affect our engine life. And the properties are inter-related each other if we try to change one property to make it compatible for the engine we may alter the other property which may extremely affects our engine life in another way.
2. The major causes of engine malfunction due to lubricant quality are deposit formation, contamination, oil thickening, oil consumption, ring sticking, corrosion and wear. Such effects are caused due to the property of the fuel used to run the engine and also the environment in which the engine operates affects lubricant stability.
3. The kinematic viscosity of the blended fuel is 5.83 cSt which is greater than 5.5 cSt and density 0.8660g/ml which is slightly higher than diesel fuel viscosity and density

respectively and this leads to high carbon deposit and engine component wearing when we compare to diesel fuel. Engine component wearing and carbon deposit forming effects are minimized when it is compared with an engine run with straight vegetable oil of Jatropha curcas oil.

4. In this study the lubricant property has been characterized and even though some changes are registered the engine works well and it can be conclude that blending of Jatropha oil with diesel fuel up to ratio of 20% gives a promising result to use it as alternative fuel for diesel engine.

5.2 Recommendation

Finally as a recommendation a high carbon deposit formed while using straight vegetable oil to run diesel engine can be minimized by modifying the fuel. Modification of the fuel needs a careful study which uses engines for long run test.

1. To study the wearing effect of this B20 the engine should be new and unused so that it can be compared how much the wear has been reduced from straight vegetable oil.
2. The performance test of the B20 could be done and the other properties like Cetane number, calorific value, sulfur content, copper corrosion, aromatics and other diesel related fuel properties can be characterized and studied.
3. The university should allow the students to use resources found in the campus to do researches like emission analyzer equipment and performance testing machine.
4. For Ethiopian Petroleum Enterprise the cost of the ASTM tests should be minimized especially for students like graduate students research.
5. ASTU must have ASTM testing laboratories in order to minimize the cost and troubles that the student are facing.

Future work

1. Further study on Jatropha oil and optimization of its blend with diesel should be done due to its great importance for the users of small scale and industrial engines especially for stationary engines.
2. For the country like Ethiopia Jatropha curcas oil is very promising to minimize the cost of importing petroleum based diesel so studies must be done to improve the production of Jatropha and blending process of Jatropha vegetable oil with diesel fuel.
3. B20 of Jatropha oil and diesel fuel runs the engine well but studies has to be conducted for further reduction of carbonaceous deposits using additives and other methods.
4. Investigation of Jatropha vegetable oil for industrial application especially sugar factories.

References

[1] B. D. R. S. Panua, "An experimental study on performance and emission characteristics of vegetable oil blends with diesel in a direct injection variable compression ignition engine.," *Elsevier,* 2014.

[2] Barsic N.J. and Hunke A.L, "Performance and emission characteristics of a DI compression ignition engine operated on Honge, Jatropha and sesame oil methyl esters," *elsevier,* vol. Renewable Energy 33 , 2008.

[3] S. J. 2. M. S. 3. Gaurav Dwivedi 1, "Diesel engine performance and emission analysis using biodiesel from various oil sources," *J. Mater. Environ. Sci. 4 (4) (2013) 434-447,* no. ISSN : 2028-2508, 2013.

[4] R. S. G. S. M. R. Silambarasan*, "Effect Of Cmpression Ratio On Performance And Emission Characterstics Of Biodiesel Blend Operated With VCR Engine," *Journal of Chemical and Pharmaceutical Sciences,* 2015.

[5] B. Demssie, "Biodiesel production optimization and quality assesment using Jatropha Curcas oil and ethanol alcohol," p. 8, 2011.

[6] S. S. P. Romano, Dielectric Spectroscopy in Biodiesel Production Characterization, springer, 2011.

[7] Gubitz GM, Mittelbach M, Trabi M, "Exploitation of the tropical oil seed plant Jatropha curcas," pp. 73-82, 1999.

[8] K. WM, "Jatropha as vegetable source of renewable energy," 2002.

[9] E. P. Foidl N, "Agro-industrial exploitation of Jatropha," 1997.

[10] M. M. R. A. D. a. S. K. Vijittra Chalatlon1, "Jatropha oil production and an experimental investigation of its use as an alternative fuel in a DI diesel engine," *Journal of Petroleum Technology and Alternative Fuels,* pp. 76-78, 2011.

[11] O. E. H.-D. E. Forson FK, "Performance of Jatropha oil blends in a diesel engine," *Renew. Energ. 29(7): 1135-45,* 2004.

[12] B. Matthäus, Technological innovations in major world oil crops, springer, 2012.

[13] N. H, "Preliminary technological operations Rapeseed –chemistry and technology.," *Elsevier*, 1990.

[14] W. Parawira, "Biodiesel production from Jatropha curcas: A review," *Academic Journals,* vol. Vol. 5(14), 2010.

[15] A. G. A. a. S. M. Omer, "Physical and Chemical Properties of Jatropha Biodiesl," 2015.

[16] Q. GR, "Developments in use of vegetable oils as fuel for diesel engines," *ASAE Paper, No. 80-1525,* 1980.

[17] *. N. K. b. Y. D. J. a. K. B. L. a. Bhupendra Singh Chauhan a, "Performance and emission study of preheated Jatropha oil on medium capacity diesel engine," *ScienceDirect,* vol. Energy 35 (2010) 2484e2492, no. 2009, 2010.

[18] A. S. J. a. C. M. Ramadhas, "Biodiesel production from FFA rubber seed oil," *Fuel, 84: 335-340..*

[19] Agarwal AK, "Biofuels (alcohols and biodiesel) applications as fuels for internal combustion engines.," *Prog. Energ.,* vol. Combust.Sci 33, no. 233-271, 2007.

[20] R. O. a. M. O. Gerhard Knothe, Biodiesel: the use of vegetable oils and their derivatives as alternative diesel fuels. In: Fuels and Chemicals From Biomass, UNIV OF MICHIGAN ANN ARBOR, 1997.

[21] K. Pramanik, "Properties and use of jatropha curcas oil and diesel fuel blends in compression ignition engine," *Renewable Energy,* 2003.

[22] R. K. Agarwal AK, "Experimental investigations of performance and emissions of Karanja oil and its blends in a single cylinder agricultural diesel engine," *Appl. Energy, 86(1): 106-112*, 2009.

[23] Pramanik K, "Properties and use of Jatropha oil and diesel blends in compression ignition engine.," *Renewable Energy, 28: 239-248.,* 2003.

[24] A. Hargot, "Experimental Investigation of The Effect of Jatropha Straight Vegetable oil (JSVO) Fuel on Small scale Diesel Engine Lubricating oil Properties and Hardware.," 2016.

[25] S. E. a. J. Y, "Production of biodiesel: a technical review.," *Renew Sustain Energy,* no. Rev 15:4732–4745, 2011.

[26] H. Z. L. X. Z. W.-g. J.-g. De-gang Li*, "Physico-chemical properties of ethanol–diesel blend fuel and its effect on performance and emissions of diesel engines," *elsever renewable energy.*, 2004.

[27] "fuels and chemicals from biomass".

[28] F. A. a. A. J. Umer Rashid, "Jatropha curcas seed oil as a viable source of biodiesl," *Pak. J. Bot.,*, Vols. 42(1): 575-582., 2010.

[29] M. M. M. R. a. A. A. GalibKazi Mostafijur Rahman, "Biodiesel from Jatropha Oil as an Alternative fuel for diesel engine," *IJMME,* vol. Vol:10 No:03, 2010.

[30] G. S. E. L. M. Romano SD, "Biodiesel. In: Combustibles Alternativos," *Ediciones Cooperativas, Buenos Aires,* 2006.

[31] K. A. N. H. Fukuda H, "Biodiesel fuel production by transesterification of oils.," *Biosci Bioeng 92(5):405–416,* 2001.

[32] D. R. B. M. Knothe G, "Biodiesel: the use of vegetable oils and their derivatives as alternative diesel fuels.," 1997.

[33] K. N. J. Y. L. K. Chauhan BS, "Performance and emission study of preheated Jatropha oil on medium capacity diesel engine," *Energy, 35: 2484-2492,* 2010.

[34] S. A. D. M. P. E. H. A. Goering CE, "Fuel properties of eleven vegetable oils," *ASAE Paper, No. 81-3579,* 1981.

[35] R. M. Bari S, "Prospect of rice bran oil as an alternative to diesel," *Proc. of the Fifth Int. Conf. on small engines, their fuels and the environment. The Universty of Reading, UK.,* pp. pp. 31-36, 1995.

[36] M. H. A. A. Sapaun SM, "The use of palm oil as diesel substitute," *Power Energy (Part A) 210,* pp. 47-53, 1996.

[37] H. M. M. M. Kalam MA, "Exhaust emission and combustion evaluation of coconut oil-powered indirect injection diesel engine.," *Renewable Energy, 28: 2405–2415,* 2003.

[38] B. Y. He Y, "Study on cottonseed oil as a partial substitute for diesel oil in fuel for single-cylinder diesel engine," *Renewable Energy,30: 805-813,* 2005.

[39] Y. F. Çetin M, "The use of hazelnut oil as a fuel in prechamber diesel engine," *Appl. Therm. Eng. 27: 63-67,* 2007.

[40] A. H. Hazar H, "Performance and emission evaluation of a CI engine fueled with preheated raw rapeseed oil (RRO)-diesel blends," *Appl. Energy, 87(3): 786-790,* 2010.

[41] M. B. Yilmaz N, "Effects of preheating vegetable oils on performance and emission characteristics of two diesel engines.," *Biomass Bioenerg., 35: 2028-2033.,* 2011.

[42] S. No, "Inedible vegetable oils and their derivatives for alternative diesel fuels in CI engines.," *Energy Rev., 15: 131-149.,* 2011.

[43] R. V. R. P. N. a. A. V. Yarrapathuni VHR, "Jatropha oil methyl ester and its blends used as an alternative fuel in diesel engine," *Therm. Sci., 13(3): 207-17.,* 2009.

[44] P. S. Singh RK, "Characterization of Jatropha oil for preparation of biodiesel," *Nat. Prod. Radiance, 8(2): 127-132,* 2009.

[45] F. Technology, "Renewable Fuel Blending Solution," 2007.

[46] American Bureau of Shipping, "notes on heavy fuel oil," 1984.

[47] Service Manual for model Robin Dy-23 engine..

[48] S. D. R. a. P. A. Sorichetti.

[49] H. a. Boa, 2004.

Appendix

Appendix A

Telefax 251 - (0)11 - 551 29 38
251 - (0)11 - 551 79 56
251 - (0)11 - 554 19 05
Email - eth-petroleum@ethionet.et

Telephones:
P.B.X. (251) - 011 - 551 32 88,
Direct: (251) - 011 - 551 00 45,
(251) - 011 - 552 60 30,
(251) - 011 - 554 19 04,
P.O.Box 3375
Addis Ababa - Ethiopia

የኢትዮጵያ ነዳጅ አቅራቢ ድርጅት
ETHIOPIAN PETROLEUM SUPPLY ENTERPRISE

Ref. No 5011/ቴ.1-3-4-4/2009

02 ግንቦት 2009

ለአዳማ ሳይንስና ቴክኖሎጂ ዩኒቨርስቲ
አዳማ

በ17/08/2009 ዓ.ም በቁጥር MSVE/0040/3/2009 በተፃፈ ደብዳቤ በሜካኒካል ሲስተምና ቬይክል ኢንጅነሪንግ ምህንድስና የአውቶሞቲቭ ኢንጅነሪንግ ድህረ ማስተርስ ተማሪ ግርማቸው አሻግሬ አማካኝነት የተላከ የነዳጅ ናሙና እንዲፈተሽላችሁ በጠየቃችሁት መሰረት የፍተሻው ውጤት ከዚህ እንደሚከተለው ቀርቧል።

S/N	Property	Test method (ASTM)	Limit	TEST RESULT FOR B_{20}
1.	Density@15°C, g/ml	D 4052	Report	0.8660
	Density@20°C, g/ml	D 4052	Report	0.8623
2.	Distillation	D 86		
	IBP, °C		-	206.0
	10% volume, recovered, °C		-	241.5
	40% volume, recovered, °C		-	302.0
	50% volume, recovered, °C		-	315.5
	90% volume, recovered, °C		282 - 362	356.0
	95% volume, recovered, °C		-	359.0
	FBP, °C, max		390	361.0
3.	Flash Point (PMCC), °C	D 93	Min 66	92
4.	Kinematic viscosity at 40 °C	D 445	1.9-5.5	5.83
5.	Total Acidity, mgKOH/g	D 974	Max 0.05	1.12
6.	Cloud point , °C	D 2500	Max. +5	+2

- The results in this report relate only to the sample tested.

ከሰላምታ ጋር

ወለላው ተክ ማሪያም
ተ/የነዳጅ ጥራት ቁጥጥር
አገልግሎት ኃላፊ

የኢትዮጵያ ነዳጅ አቅራቢ ድርጅት 1959 1966 Ethiopian Petroleum Supply Enterprise

ጥራቱን የጠበቀ የነዳጅ ምርት በማቅረብ የአገራችንን ልማት ለማፋጠን በሚደረገው ርብርብ ውስጥ የድርሻችንን እንወጣለን!

Appendix B

Telefax 251 - (0)11 - 551 29 38
251 - (0)11 - 551 79 56
251 - (0)11 - 554 19 05
Email - eth-petroleum@ethionet.et

የኢትዮጵያ ነዳጅ አቅራቢ ድርጅት
ETHIOPIAN PETROLEUM SUPPLY ENTERPRISE

Telephones:
P.B.X. (251) - 011 - 551 32 88,
Direct: (251) - 011 - 551 00 45,
(251) - 011 - 552 60 30,
(251) - 011 - 554 19 04,
P.O.Box 3375
Addis Ababa - Ethiopia

Ref. No. 5012/6-1.3-৫৫/20৫

0 2 ግንቦት 2009

ለአዳማ ሳይንስና ቴክኖሎጂ ዩኒቨርስቲ
<u>አዳማ</u>

በ17/08/2009 ዓ.ም በቁጥር MSVE/0040/3/2009 በተፃፈ ደብዳቤ በሜካኒካል ሲስተምና ቬይክል ኢንጅነሪንግ ምህንድስና የአውቶሞቲቭ ኢንጅነሪንግ ድህረ ማስተርስ ተማሪ ግርማቸው አሻግሬ አማካኝነት የተላከ Used oil ናሙና እንዲፈተሽላችሁ በጠየቃችሁት መሰረት የፍተሻው ውጤት ከዚህ እንደሚከተለው ቀርቧል፡፡

S/N	Property	Test method (ASTM)	TEST RESULT FOR USED OIL
1.	Density@15°C, g/ml	D 4052	0.8927
	Density@20°C, g/ml	D 4052	0.8898
2.	Flash Point (PMCC), °C	D 93	>100
3.	Kinematic viscosity at 40 °C	D 445	5.83
4.	Conradson Carbon Residue, %Wt.	D 189	1.50
5.	Ash Content, %Wt.	D 482	0.98

- The results in this report relate only to the sample tested.

ከሰላምታ ጋር

ወሰላው ተክ
ተ/የነዳጅ ጥራት ማረጋገጫ
አገልግሎት ኃላፊ

የኢትዮጵያ ነዳጅ አቅራቢ ድርጅት 1959 1966 Ethiopian Petroleum Supply Enterprise

ጥራቱን የጠበቀ የነዳጅ ምርት በማቅረብ የአገራችንን ልማት ለማፋጠን በሚደረገው ርብርብ ውስጥ የድርሻችንን እንወጣለን!

Appendix C

Indian Standard
METHODS OF TESTS FOR INTERNAL COMBUSTION ENGINES
PART V PREPARATION FOR TESTS AND MEASUREMENTS FOR WEAR
IS: 10000 (Part V) – 1980 (Reaffirmed 2001) Edition 1.1 (1985-03)

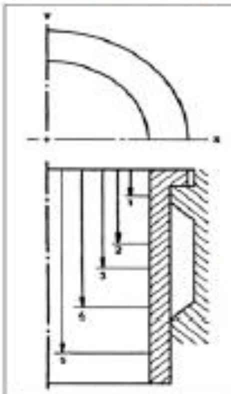
- Proformae For Recording Dimensions Of Critical Components Of Engines And Measurements For Wear After Endurance Tests

6. Measurements for Wear

6.1 *Final Inspection* — At the completion of type tests, the engine shall be dismantled. Its condition shall be noted and the dimensions of critical parts mentioned in **3** shall be recorded in the proformae given in Appendix A.

6.1.1 The wear of critical components shall be recorded in proformae given in Appendix A and shall be compared with the declarations made by the manufacturer.

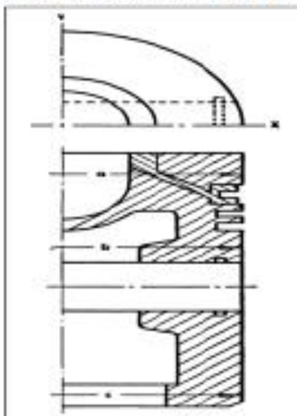
A-2. Measurements of Cylinder Bore/Cylinder Liner



	Dimensions at Positions Indicated in Fig.														
	Before Endurance Test					After Endurance Test					Wear				
	1	*2*	*3*	*4*	*5*	*1*	*2*	*3*	*4*	*5*	*1*	*2*	*3*	*4*	*5*
Along Crank-shaft Axis															
Perpen-dicular to the Crank-shaft Axis															

Surface Condition (specify) (Add or Cross Out)	Burning, Pitting, Erosion, Scratches, Warping, etc

A-3. Measurement of Piston Dimensions — (*See also* IS : 8503-1977 Technical supply conditions for pistons for I. C. Engines).

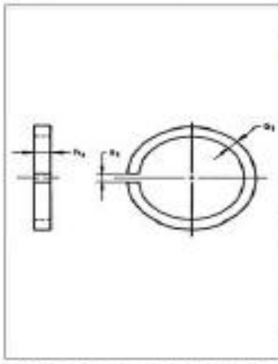


		Before Endurance Test		After Endurance Test		Wear	
		ϕX	ϕY	ϕX	ϕY	ϕX	ϕY
Diameter of Piston at Position	*a*						
	b						
	c						

Surface Condition (Specify)	Crown	
	Top Land	
	Skirt	

Note — Measurements shall be made for each piston.

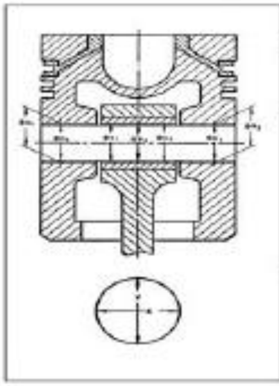
A-4. Measurements for Piston Rings — (*See also* IS : 5791-1977*)



Ring No.	Dimensions of Piston Rings																
	Before Endurance Test						After Endurance Test						Wear				
	Radial Wall Thickness a_1	Ring Closed Gap, s_1 when in the Nominal Bore Specified in IS : 3511†		Axial Width h_1	Surface Condition (Specify)		Radial Wall Thickness a_1	Ring Closed Gap, s_1 when in the Nominal Bore Specified in IS : 3511†		Axial Width h_1	Surface Condition (Specify)		Radial Wall Thickness a_1	Ring Closed Gap, s_1 when in the Nominal Bore Specified in IS : 3511†		Axial Width h_1	
		Compression	Oil control					Compression	Oil control					Compression	Oil control		
1																	
2																	
3																	
4																	
5																	

Note — These measurements shall be taken for each cylinder.

A-5. Measurements of Gudgeon Pin, Pin Bore and Small End Bush of Connecting Rod



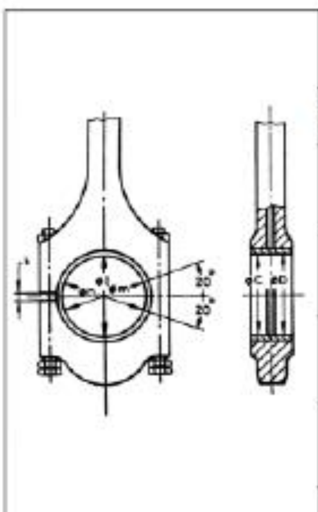
	Dimensions										
	Before Endurance Test										
	Gudgeon pin bore (in piston)		Gudgeon pin diameter			Clearance between		Small end bush		Clearance between	
	ϕa_1	ϕa_2	ϕb_1	ϕb_2	ϕb_3	ϕa_1 and ϕb_1	ϕa_2 and ϕb_3	ϕc_1	ϕc_2	ϕb_2 and ϕc_1	ϕb_2 and ϕc_2
X											
Y											

		Before Endurance Test	After Endurance Test
Surface Condition	Gudgeon Pin	Specify	Burnt, Pitted, Scored, Corroded, Lacquered, Other (Specify)
	Small End Bush	Specify	Burnt, Pitted, Scored, Corroded, Lacquered, Other (Specify)

Note — These measurements shall be taken for each cylinder.

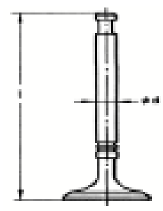
IS : 10000 (Part V) - 1980

A-10. Measurement of Connecting Rod Bearing Bore



		Dimensions																	
		Before Endurance Test						After Endurance Test						Wear					
Cylinder number		1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
ϕC	ϕl																		
	ϕm																		
	ϕn																		
ϕD	ϕl																		
	ϕm																		
	ϕn																		
Gap k																			

A-12. Measurements for Inlet and Exhaust Valves — [*see also* IS : 810-1974 Specification for inlet and exhaust valves for I. C. engines (*first revision*)].

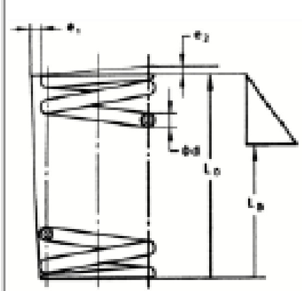


		Dimensions		
		Before Endurance Test	After Endurance Test	Wear
Stem Diameter d	Inlet valve			
	Exhaust valve			
Length l	Inlet valve			
	Exhaust valve			

Surface Condition (Specify)		Valve Stem	Valve Face
	Inlet		
	Exhaust		

Note — The measurements shall be taken for each cylinder.

A-15. Measurements for Valve Springs and Governor Springs (Wherever Applicable) — [*see also* IS : 7906 (Part I)-1976 Helical compression springs: Part I Design and calculations for springs made from circular section wire].



		Before Endurance Test						After Endurance Test						Wear					
		Un-loaded Length L_0	Block Length L_B	Spr-ing Rate S_c	Wire Dia-meter d	e_1	e_2	Un-loaded Length L_0	Block Length L_B	Spr-ing Rate S_c	Wire Dia-meter d	e_1	e_2	Un-loaded Length L_0	Block Length L_B	Spr-ing Rate S_c	Wire Dia-meter d	e_1	e_2
Valve Spring	Inlet																		
	Ex-haust																		
Gover-nor Spring (if Appli-cable)																			

Note — These measurements shall be taken for each spring.

The revised methods of tests covered by IS: 10000 have been aligned with the current international practices in the field of I.C. engines. These parts are in general agreement with the following ISO standards, issued by the International Organization for Standardization:

a) ISO 3046/I-1975 Reciprocating internal combustion engines — performance: Part I Standard reference conditions and declarations of power, fuel consumption and lubricating oil consumption
b) ISO 3046/II-1977 Reciprocating internal combustion engines — performance: Part II Test methods
c) ISO 3046/III-1979 Reciprocating internal combustion engines — performance: Part III Test measurements
d) ISO 2710-1978 Reciprocating internal combustion engines — vocabulary This Part V of IS: 10000 covers the procedure for measurement of wear of critical components for engines. Although the wear after the endurance test has not been specified, it is expected that data collected by implementation of this standard will enable the committee to lay down the specification limits for acceptance at a later date.

Appendix D

Indian Standard

METHODS OF TESTS FOR INTERNAL COMBUSTION ENGINES

PART IX ENDURANCE TESTS

[Ref : Doc : EDC 14 (5130)]
and Codes of Practice for Engines Subcommittee, EDC 14 : 3
Internal Combustion Engines Sectional Committee, EDC 14; Methods of Test

1. Scope — Specifies the method of conducting endurance tests on constant speed and variable speed internal combustion engines.

2. Section I — Endurance Tests for Constant Speed Engines — These tests shall be performed after the initial performance tests specified in IS : 10000 (Part VIII)-1980 'Methods of tests for internal combustion engines: Part VIII Performance tests'.

2.1 After completion of the initial performance test the engine shall be run for 32 cycles (each of 16 hours continuous running) at rated speed.

2.1.1 *Test cycle for IS Rating A*

Load (*Percent of Rated Load*)	*Running Time* (Hours)
100	4 (including warm-up period of 0·5 h)
50	4
110	1
No load (Idling)	0·5
100	3
50	3·5

2.1.2 *Test cycle for IS Rating B*

Load (*Percent of Rated Load*)	*Running Time* (Hours)
100	4 (including warm-up period of 0·5 h)
50	4
100	1
No load (Idling)	0·5
100	3
50	3·5

2.2 At the end of each 16 hours cycle, the engine shall be stopped and necessary servicing and minor adjustments may be carried out in accordance with the manufacturer's schedule.

2.3 Before starting the next cycle, the temperature of the engine sump oil shall have reached within 5 K of the room temperature.

2.4 The engine shall be topped up with engine oil, if required and the quantity consumed recorded. In case the duration of the endurance test is longer than the period of oil change recommended by the engine manufacturer, the oil shall be changed according to the manufacturer's recommended schedule. The amount of make up oil used during the tests shall be used to establish the lubricating oil consumption rate.

Adopted 31 December 1980	© May 1981, BIS	Gr 2

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002