THE EFFECT OF MAGNETIZED CASTOR OIL BIODIESEL BLENDED WITH PETRODIESEL FUEL ON ENGINE PERFORMANCE AND EMISSION CHARACTERISTICS

by

Sisay Suyume

A Thesis Submitted to Department of Mechanical Systems and Vehicle Engineering

School of Mechanical, Chemical and Materials Engineering

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Advisor: N.Ramesh Babu (PhD)

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DECLARATION

I declare that the MSc thesis entitled: '**The Effect of Magnetized Castor Oil Biodiesel Blended with Petrodiesel Fuel on Engine Performance and Emission Characteristics**' is my own work, that it has not been submitted for any degree or examination in any other university, and that all the sources I have used or quoted have been indicated and acknowledged as complete reference.

Candidate	Signature	Date

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

Advisor	Signature	Date

Approval Page

We, the undersigned, members of the Board of Examiners of the final open defense by Sisay Suyume Sima have read and evaluated his thesis entitled "The Effect of Magnetized Castor Oil Biodiesel Blended with Petrodiesel Fuel on Engine Performance and Emission Characteristics" and Examined the candidate. This is therefore to certify that the thesis has been accepted in partial fulfillment of the requirement of the degree of Master of Science in Automotive Engineering.

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NOMENCLATURE

Abbreviations	Description
B0	Diesel
B100	100% Biodiesel
B20	20% Biodiesel
Bp	Brake power
BSFC	Brake specific fuel consumption
BTE	Brake thermal efficiency
CB	Castor biodiesel
CH_3 OH	Methanol
CI	Compression ignition
CN	Cetane number
CO	Carbon monoxide
CO2	Carbon dioxide
COB	Castor oil biodiesel
COME	Castor oil methyl ester
CP	Cloud point
CR	Compression ratio
D95C05	95% Diesel and 5% castor oil biodiesel
DI	Direct injection
FAEE	Fatty acid ethyl ester
FAME	Fatty acid methyl ester
FFA	Free fatty acid
g/ml	Gramm per mililiter
HC	Haydro carbon
KOH	Potassium hydroxide
kw	Kilowat
L	Liter
m_f	Mass of fuel flow
MJ/kg	Mega joule per kilogram

ml	Milliliter
ml/min	Milliliter per minute
mm^2/s	Square millimeter per second
MPa	Mega pascal
NaOH	Sodium hydroxide
N-m	Newton-meter
NOx	Nitric oxide
O_2	Oxygen
OHV	Over Headed Valve
OS	Oxidation stability
ppm	Parts per molecule
RC	Recinoilic Castor
RPM	Revolution per minute
sfc	Specific fuel consumption
SIE	Spark ignition engine
Tb	Brake torque
TG	Triglycerol
v_f	Volume rate of fuel flow
W	Watt
w/w	Weight per weight
wt.	Weight
ρ_f	Density of fuel
DT	Distillation temperature
KV	Kinematic viscosity

ABSTRACT

Biodiesel produced from edible and non-edible vegetable oil and animal fatty acids is one of the most alternative fuel's candidates to replace petrol-diesel fuel. Because, in that respect is no topic of competition in the nutrient market, non-edible vegetables are preferable for biodiesel production. Biodiesel produced from castor oil, which is nonedible, was taken in this study. The chief problem of castor oil biodiesel is that, it has very high viscosity which leads to incomplete burning. In this research the engine operation and emission characteristics of, single cylinder, four stroke, diesel engine fueled with the blend of castor oil, biodiesel and Petro diesel was evaluated by applying magnetic force in the fuel inlet line to energize the fuel and improve the combustion. The results indicate that a small reduction in brake power and brake torque for B20 with and without magnet when compared to mineral diesel. The fuel consumption was increased by 3.25% and 1.45% for B20 and magnetized B20 respectively. But the emissions were substantially improved for B20 in both magnetized and none magnetized cases. The emission of CO was reduced by 7.17% and 13.52% for B20 with and without magnet when compared to B0. Similarly, the HC was reduced by 16% and 23% for B20 with and without magnet respectively. The O_2 emission was increased for B20 and magnetized B20 by 10% and 14% with respect to B0. The CO_2 was increased by 5.9% and 2.2% for B20 and magnetized B20 respectively. It was observed that magnetic force improves engine performance and emission characteristics by ionizing the fuel; so that there was complete combustion in the engine. Thus permanent magnet can be used for B20 for better engine performance.

Keywords: *biodiesel, castor oil, magnetization, transesterification, performance and emission*

CHAPTER ONE

INTRODUCTION

1.1 Background

The extreme growth of the human population and industrialization of our world leads to the permanent increment of consumption of petroleum, which has caused depleting fossil fuel reserves and increasing petroleum price. On the other hand, the combustion of this fossil fuel pays most to emissions of greenhouse gases, which lead to atmospheric pollution and global warming.

The transport section is almost extremely dependent on fossil fuels. The increase of the number of transport vehicles, as predicted, could affect the stability of the environment and climate on the whole planet. Therefore, there is a great awareness in a diesel fuel substitution in the present all over the entire world with a clean, renewable fuel such as biodiesel, which has a lot of technical advantages over fossil fuels such as lower overall exhaust emission and toxicity, biodegradability, derivation from a renewable and domestic feedstock, negligible sulphur content, superior flash point and higher combustion efficiency (Ramesh et al, 2018).

The biodiesel could be used as pure fuel or as a blend with petroldiesel, which is stable in all ratios. Biodiesel production is predicted to inspire employment and economic development in rural areas, to progress long term substitution of fossil fuels, to reduce national reliance on the petroleum import and to increase the security of energy supply.

Even though biodiesel has a lot of advantages in related to petrol diesel, the high price of its production is the main barrier to its commercial use. The use of inexpensive non-edible oils can be a method to increase the economy of biodiesel production and its commercial production at the industrial scale. Based on their climate conditions, many countries have been looking for various types of non-food vegetable oils for promising use in biodiesel production. One source of non-food vegetable oil potential for diesel fuel is castor oil.

The castor seed production has been increasing over all the world throughout the years, the major producer being India, China, and Brazil. The major importers of castor oil are the USA, European countries, Russia, Japan and China (Beruk et al, 2018).

Castor oil can be produced from the castor seed by various methods such as mechanical pressing and solvent extraction using various solvents (Carlos et al, 2020). (Ogunniyi et al, 2006) gave an indication that mechanical pressing give yields less than the soxhlet extraction method and also that oils produced using different methods have different physicochemical properties. (Patel et al, 2016) further showed that mechanical pressing can be improved significantly by increasing the working temperature and the leftover oils can be extracted organic solvents.

The conversion rate and characteristics of castor oil found from various countries of the world provided different results due to dissimilar geographical and climatic conditions. Most of the castor oil found in the world has been studied by different researchers based on conversion rate, properties, and fatty acid composition. (Beruk et al, 2018), studied on Ethiopian castor to determine the conversion rate and physicochemical characteristics of the oil extracted using different mechanisms. Oil extracted mechanically and chemically (soxhlet) were characterized to qualitatively differentiate the effect of extraction process on the characteristics of the oil, especially on the fatty acid composition.

It is a triglyceride derived from ricinoleic acid, which constitutes 90% of fatty acids present in the molecule and 10% non-hydroxylated fatty acids, mainly by oleic and linoleic acids (Nevea et al, 2013). The high content of ricinoliec acid in castor oil allows to highly soluble in alcohol at room temperature which facilitates several chemical reactions. Castor oil has a higher viscosity than diesel oil, making it difficult to atomize in the combustion chamber. The high viscosity of Castor oil is due to the lack of double bond in triglyceride molecule plus long HC tail on fatty acid molecule. Therefore, it is essential to decrease the viscosity ofvcastor oil so that it can be used as a possible alternative fuel for diesel engines. The problem owing to the high viscosity of vegetable oil has been reported in several ways, such as preheating, mixing or diluting with other fuels, transesterification, and thermal cracking or pyrolysis.

In fact, it is common to mix vegetable oil with diesel fuel. The power generated from diesel engine fuelled with castor biodiesel oil is slightly smaller than the one with the use of diesel fuel due to the lower calorific value of biodiesel (Keera et al, 2018). The decrease in engine thermal efficiency with an increase in the proportion of castor oil is related to the incomplete combustion of castor oil because of high viscosity and low volatility. It is critical to improving the combustion process of castor oil in term of decreasing its viscosity. Giving magnetic field on castor fuel before entering the combustion chamber is one of the solutions to reduce the viscosity. The use of magnet established throughout the fuel flow pipe facilitates the binding of oxygen atoms by fuel during the combustion process (Farrag et al, 2010).

1.2 Biodiesel

Biodiesel is an alternative fuel formulated exclusively for diesel engines and its blend can used in diesel engines without any modification of the components of the vehicles. It is produced from vegetable oil or animal fats or it is the name for a variety of ester based fuels generally defined as the mono alkyl esters made from vegetable oils through simple transesterification reaction. Some of the advantages and disadvantages of biodiesel as follows (Santos et al, 2013);

1.2.1 Advantages of Biodiesel

- ✓ is not toxic
- ✓ is biodegradable
- ✓ is safer to handle compared to standard diesel
- ✓ can be easily blended with standard diesel, and it can be used in most of today's vehicle even in form of pure biodiesel B100
- ✓ can help cut our reliance on fossil fuel, and improves our energy security and energy independence
- ✓ Production and use of biodiesel accounts for significantly less emissions compared to standard diesel
- ✓ has very good lubricating properties, significantly better than standard diesel which can prolong engines life.
- ✓ has no sulphur content, and so it doesn't contribute to acid rain formation

1.2.2 Disadvantages of Biodiesel

- Biodiesel can increase the emission of nitrogen oxide which can lead to the formation of smog
- Biodiesel has significantly less energy content compared to standard diesel
- Pure biodiesel has significantly problem with low temperature
- Slightly higher nitrous oxide (NO_x) emissions than diesel fuel

- Higher production cost

1.2.3 Biodiesel Production

There are four methods for biodiesel production. Those are blending, pyrolysis, micro emulsion and transestrefication. Among all transestrification is viable process of the biodiesel production, because it is relatively the cheapest way with good fuel properties. The overall process of the transesterification reaction using castor oil and methanol in the presence of catalyst is as shown in Figure 1.1.

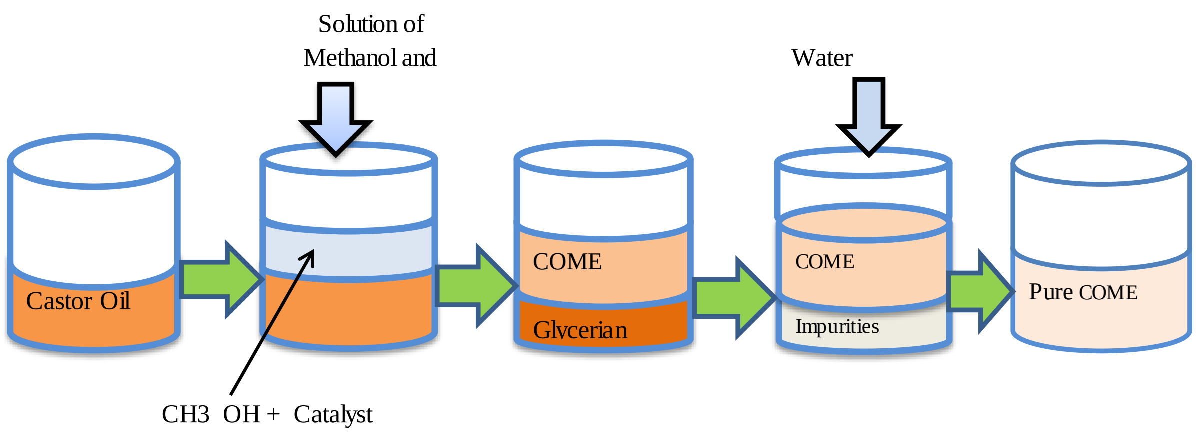

Figure 1.1 Biodiesel extraction process

1.3 Fuel Magnetization

In the combustion of hydrocarbon fuels, it is the outer shell of the hydrogen that is combusted first, it possesses two distinctive forms: ortho-hydrogen and para-hydrogen. To secure conversion of para to ortho state, it is necessary to change the energy of interaction between nuclear spins. The molecules of the two gases, para and ortho-hydrogen differ in the relative orientation of the nuclear spins of the two protons. In para molecules the spins of the protons are anti-parallel, while in the ortho molecules occupying the even rotational levels and the ortho molecules occupy the odd levels.

The orientations of the spins have a pronounced effect on the behavior of the molecule. In fact, ortho-hydrogen is unstable and more reactive than its para-hydrogen counterpart (Vijay et al, 2014).

1.3.1 Fuel Ionization

The molecules of any gas or liquid carry positive or negative electric charges. These molecules get attracted to each other and form ‘cluster’. In such condition, when the fuel is mixed with air, all the molecules of the fuel may not combine with the oxygen molecules in the air, in order to burn and give out heat energy. Some of the fuel molecules burn and the rest escape in the atmosphere as un-burnt gases. This leads to poor fuel efficiency and pollution of the atmosphere.

In the presence of the magnetic field created by the permanent magnets’ the fuel molecules are oriented in a particular direction and the molecular clusters are opened out. This is called ‘ionization’. Ionized fuel molecules combine with oxygen molecules in the air quickly and burn effectively. This more effective burning increases the flame temperature and higher heat energy, leading to fuel saving and reduction of air pollution.

1.4 Statement of the Problem

Biodiesel produced from edible source has a competition in the nutrient market, and this can cause them to high price of its production, which leads a doubt as a long term subsititution of fossil fuels. On the otherhand, some essential properties of biodiesel such as viscosity, melting point, and cetane number has straight relation with the chemical composition of the biomass source used. The lack of double bond in the triglyceride molecule plus a long HC tail of the fatty acid molecule contributes to the high viscosity of castor oil. High density biodiesel is not favourable as it can lead to incomplete combustion and particulate matter emissions. Fuels do not combust until they are vaporized and mixed with air. The production of exhaust particulate matter in diesel and other incomplete combustion products are as a result of incomplete atomization of spray drops within the short time for the mixture. Because, in that respect is no topic of competition in the nutrient market, non-edible vegetables are preferable for biodiesel production as long term substitution of fossil fuels. Ionization is highly beneficial to facilitate the fuel in binding with oxygen during the combustion process. The size of the fuel can be transform into smaller bonds when the fuel is subjected to magnetization.

1.5 Objectives

1.5.1 General Objective

To experimentally investigate the effect of magnetized castor oil biodiesel blend with petrodiesel fuel on the performance and emission characteristics of diesel engines.

1.5.2 Specific objectives

- extract oil from castor seed
- produce biodiesel from castor oil by transesterification
- test the properties of biodiesel
- test the blended biodiesel fuel on the diesel engine and analyze the performance and emission characteristics of the engine.

1.6 Significance

- Reduce dependence on depleting fossil fuels and ensure a sustainable source of fuel
- Reduce emissions
- Promote castor oil biodiesel
- Increase the demand of castor seed and, there motivate farmers to focus on producing castor seed and improve their income

1.7 Scope

The research has been concentrated on the effect of magnets on the castor oil biodiesel during its combustion in the engine and the performance and emission characteristics of the engine that used a blend of castor biodiesel and petrodiesel energized by magnetic force.

1.8 Beneficiary

- Farmers from seed production
- Automotive manufacturer
- Governments, reduces cost import for petrodiesel
- Population from less emission

1.9 Thesis Organization

This thesis paper is organized in five chapters.

Chapter one: **Introduction,** deals about the background of biodiesel, international energy demand and the biodiesel hopes of representing diesel fuels, the statement of the problem, objective and significance of this work.

Chapter Two: **Leterature Review**, discusses literature reviews, biodiesel production, fuel properties, effect of magnetizing the fuel.

Chapter Three: **Materials and Methods**, the materials used and methodology of the work is presented in details.

Chapter Four: **Results and Discussion**, is talking about the results found in this work and discussed in details.

Chapter Five: **Conclusion and Recommandation**, includes the conclusion of the work, recommendations and future works.

CHAPTER TWO

LETERATURE REVIEW

Introduction

In this chapter the work of different authors and their results has been discussed in detail. In addition to this the biodiesel source and its production methods has also been discussed. The effect of magnetic force on the fuel ionization and its working principles was also explained. Finally the research gap and the way to fill the gap was given.

2.1 Introduction

The production of biodiesel from vegetable oils as an alternative fuel for diesel engines has been considered by many researchers. But from the results of all studied research it has been noted that the direct use of vegetable oils in engines is limited by some physical properties including its high viscosity, low volatility, and the fact that it is polyunsaturated. As a result, the use of oil without chemical modification can cause damage to engines and create environmental problems because of its incomplete combustion. Different researches have been conducted to solve this matter.

Torrentes et al, 2017 produced biodiesel from castor oil under critical conditions using only methanol and castor oil without any catalyst. They used a 10L reactor and take 50:1 molar ration of castor oil to methanol and to increase the pressure in the reactor they add industrial nitrogen. The super temperature and pressure at which the reaction was takes place for 5 min is 2658^0C and 677Mpa respectively.

As castor oil contains higher free fatty acids, Kaniz et al, 2012 used two step-transesterification. They used sulfuric acid as catalyst in the first step reaction, that is esterification, to reduce free fatty acid content by below 2 wt.%. After the reaction the products are cooled at room temperature and washed. Then the second step reaction, which was transesterification, were takes place using sodium hydroxide as a catalyst. From their report, the viscosity of the oil was reduced to 11.6mm^2/s from 253mm^2/s. Similarly, the free fatty acid content of the oil was reduced from 13.6 wt% to 1.1 wt%.

Osman et al, 2015 also used two-step transiesterification to produce biodiesel from castor oil. In the first reaction they used 1.75gm of NaOH and 150mL of methanol for 1000mL of castor oil and allow it to react at 55^0C for 90 minutes. The glycerol was removed and the crude biodiesel were again exposed to the second transesterification reaction which used the same amount of catalyst and alcohol. In the second transesterification the reaction temperature where 75^0C and the reaction were takes place for 60 minutes. The properties of the biodiesel produced under this condition showed that the density, kinematic viscosity, calorific value, flash point, PH, copper strip corrosion and water content of 932.4Kg/m^3, 15.069mm^2/s, 38.6MJ/Kg, 182^0C, 7, 1a and 1067.7mg/Kg, respectively.

Swaroopa et al, 2017 studied the effect of factors affecting transesterification reaction to optimize the conversion rate. They focus on four factors; those are reaction time, reaction temperature, catalyst, and oil to methanol ratio. Among the four factors the increase of molar ratio and reaction time has insignificant effect on COME conversion. The optimum condition at which conversion of Castor oil to biodiesel is 3h, 1:200 oil/methanol molar ratio, 1.19wt% catalyst concentration and 30^oC reaction time. The maximum coversion rate of the oil to biodiesel under this optimum condition was found to be 97%.

Mithun et al, 2016 used one stage transesterification reaction to convert pure castor oil to castor oil methyl ester. They have been mixed Methanol (25% v/v of oil) and sodium hydroxide as catalyst (1% /w/w of oil) in a closed reagent bottle with the help of magnetic stirrer. They allowed the oil to be heated to 115^0C for 2 hours and drive off dissolved water. After they cool down the oil to 55^0C the methanol and sodium hydroxide mixture were added to the oil and the reaction were takes place for 1 hour. After they produced the biodiesel, they have conducted experimental tests on 4-stroke, single cylinder, variable compression ratio, water-cooled, multi-fuel engine to evaluate the performance parameters and emission characteristics of the engine. Their result at higher compression ratio showed that, increase in engine power, reduction in the fuel consumption, increase in the NO_x emission and reduction of CO and HC emissions.

Oliveria et al, 2005 studied the influence of NaOH concentration (0.5-1.5wt%), ethanol: oil molar ratio (3:1-9:1) and reaction time temperature (30-70^0C) and time (1-3 h). 96.2% of conversion was reached under the optimal conditions (0.5 wt.% catalyst, 3:1 ethanol: oil, 70^0C and 3 h).

Ismail et al, 2014 investigated the optimum biodiesel conversioofom crude castor oil to castor biodiesel (CB) through transesterification method. The base catalysed transesterifcation under different reactant proportion such as the molar ratio of alcohol to oil and mass ratio of catalyst to oil was studied for optimum production of castor biodiesel. The optimum condition for base catalysed transesterifcation of castor oil was determined to be 1:4.5 of oil to methanol ratio and 0.005:1 of potassium hydroxide to oil ratio. The fuel properties of the produced CB such as the calorific value, flash point and density were analysed and compared to conventional diesel. From their experiment it was observed that diesel engine performance and emission test on different CB blends proved. CB was also proved to have lower emission compared to conventional diesel. Thus they recommend that CB was suitable to be used as diesel blends.

Molla et al, 2014 analysised the fuel properties of RC biodiesel and diesel fuel blend to use castor oil methyl ester as a possible alternative fuel for diesel engines. Various properties of the RC biodiesel and their blends such as density, kinematic viscosity, iodine value, saponification number, Cetane number, heating value, flash point and acid value were determined. The experimental results were compared well with American Society for Testing and Materials (ASTM D6751) and European biodiesel standards (EN 14214). The experimental design as well as statistical analysis was done and analysed using design expert 8.0.7.1 version software. The predicted optimum conditions for castor oil biodiesel production were a reaction temperature of 59.89^0C, methanol to oil ratio of 8.10:1 and a catalyst of 1.22 wt.% of oil. Under these optimum conditions the methyl ester content was 94.5% w/w of oil, and all of the measured properties of the biodiesel met the international standards of EN14214 and ASTM D 6751 with the exception of density and viscosity. Therefore, the viscosity and density of the ester was higher and further reduced by blending with diesel fuel up to B45 to satisfy within the ASTM D6751 and EN 14214 limits for biodiesel.

Another study by Shojaeefard et al, 2013 examined the effects of castor oil biodiesel blends on diesel engine performance and emissions. They found that a 15% blend of castor oil–biodiesel was an optimized blend of biodiesel–diesel proportions. The results indicated that biodiesel blends at lower ratio provides acceptable engine performance and even improve it.

Similar to the study by Shojaeefard et al, 2013, Das et al, 2017 prepared castor biodiesel by a transesterification process using potassium hydroxide as a catalyst. They used this extracted biodiesel to carry out a series of tests on unmodified direct-injection (DI) four-stroke diesel engines in order to evaluate the performance parameters, exhaust emission and combustion characteristics. Neat biodiesel and biodiesel blended with petro diesel were compared with the baseline operation of the engine. From their results it was seen that the lower blends of biodiesel have higher thermal efficiency and reduced fuel consumption. By feeding the engine with biodiesel blend, the emission of unburned hydrocarbons, carbon monoxide and particulates are significantly reduced with increasing the engine loading condition. Lower blend shows a delay in heat release as compared to higher blends. The results prove that the use of castor as biodiesel in CI engine is a reliable alternative to diesel.

Panwar et al, 2009 prepared COME by transesterification using potassium hydroxide aa catalystst and was used in four strokes, single cylinder variable compression ratio type diesel engine. Tests were conducted at a rated speed of 1500 rpm by varying engine loads. Straight vegetable oils pose operational and durability problems when subjected to long term usages in diesel engines. These problems are attributed to high viscosity, low volatility and polyunsaturated character of vegetable oils. The transesterification process is found to be an effective technique of reducing vegetable oil viscosity and eliminating operational and durability problems. The essential properties of methyl ester of castor seed oil are compared with petrol diesel fuel. The engine performance was investigated with different blends of biodiesel and was compared with petrol diesel. It was concluded that the lower blends of biodiesel improved the brake thermal efficiency and reduced the fuel consumption. The exhaust gas temperature increased with increasing biodiesel concentration.

Sukani et al, 2017 installed the magnetic field in the fuel line of a diesel engine fuelled with jatropha-diesel by expecting the reduction of the viscosity of jatropha-diesel oil mixture, hence improve the combustion reaction process. In their research the influence of the magnetic field strength in the fuel inlet lines to the power of diesel engines fueled with a mixture of jatropha-diesel oil was studied. The composition of Jatropha oil-diesel was 20% jatropha oil and 80% diesel oil. Magnetic field variations were 0.122, 0.245 and 0.368 Tesla. The results showed that the higher the strength of the magnetic field was, the higher the average diesel engine's power would be.

Farrag et al, 2010 carried out study on engine performance parameters such as fuel consumption and exhaust emissions by applying magnetic force in the fuel inlet line. The magnetic field was applied to S.I.E. Using gasoline fuel. Moreover, the fuel is subjected to a permanent magnet mounted on fuel inlet lines. They carried out experiments at different idling engine speeds. The exhaust gas emissions of CO, NO, and CH_4 were measured by using an exhaust gas Analyzer. The magnetic effect on fuel consumption reduction was up to 15%. CO reduction at all idling speed was range up to 7%. The effect on NO emission reduction at all idling speed was range up to 30%. The reduction of CH_4 at all idling speed was range up to 40%.

Similar to Farrag, Patel et al, 2014 studied on engine performance parameters such as fuel consumption and exhaust emissions by using magnetic fuel conditioning. The experiments in current research comprise the using of permanent magnets with different field intensity (2000, 4000, 6000, 8000 Gauss) that is installed on fuel inlet lines. Mounting magnets on fuel line enhance fuel properties such as it aligns & orients, hydrocarbon molecules, better atomization of fuel that mean proper mixing of air with fuel, etc. The experiments was conducted at different engine load and at a different compression ratio. The exhaust gas emissions of CO, HC, CO_2 and NO_x will measure by using an exhaust gas Analyzer.

Farisa et al, 2012 investigated the effect of magnetic field on fuel consumption and exhaust emissions in two stroke engines. The results generated from their work include the overall performance and exhaust emission tests showed a beneficial effect. It was found that the percentages of exhaust gas components (CO, HC) were decreased considerably, but the CO_2 percentage increased up to 10%.

Jadhav et al, 2016 performed an experiment on Single Cylinder Four Stroke Diesel engine. They used magnetic field along the fuel line immediately before fuel injector. It has been reported that magnetic field serves to improve mixture formation by increasing the atomization process of the sprayer in the combustion chamber due to increasing the rate of decomposition of the droplets as a consequence of diminution in the surface tension and viscosity of the fuel. The effects of magnetic domains on the engine operation parameters such as specific fuel consumption break thermal efficiency, exhaust emissions, and so on are analysed by applying the magnetic field along the fuel line immediately before fuel injector and their results shows that reduction in fuel consumption and increase in engine performance, while the pollutants such as HC, CO, CO_2, O_2 and NOx also reduced by 5 to13%.

Kapase et al, 2018 conducted experimental tests on a single cylinder, four stroke, compression ignition engine, to evaluate the effect of using magnetic force in the fuel line. The result found in their experiment showed the reduction of fuel consumption of 12%, the percentage reduction in HC, and CO was 22% and 7% respectively. Inversely the emission of nitrogen oxide and carbon dioxide was increased by 19% and 7% respectively.

2.2 Biodiesel

Among the various alternatives which include vegetable oils, biodiesel, alcohols, natural gas, bio-gas, etc. biodiesel serves as a viable alternative. Biodiesel has many advantages over conventional petro-diesel owing to the fact that it is biodegradable, renewable, easily available, easily portable and non-toxic. Moreover, it has higher cetane number, higher flash point, lower Sulphur content and lower aromatic content than petro-diesel.

2.2.1 Biodiesel sources

Biodiesel can be produced from a variety of feedstock such as vegetable oils (edible and non-edible), waste or used cooking oil, and animal fats (such as beef tallow, pork lard). Table 2.1 shows the main feedstock of biodiesel production (Osman et al, 2015). Non-edible oils are preferred for making biodiesel compared to edible oils, in order to avoid any conflict with food supply. There are various non-edible oil-seed species, such as Jatropha curcas (Jatropha), Azadirachta indica (Neem), Pongamia pinnata (Karanja), Ricinus communis (Castor) and Madhuca indica(Mahua) (Atiya et al, 2017), which have been used to produce biodiesel. Among these, castor is a promising resource for biodiesel production because of the higher oil yield potential of castor seeds compared to the other non-edible oilseeds.

Table 2.1 Main feedstock for biodiesel production **(**Osman et al, 2015**)**

Edible oils	**Non-edible oils**	**Animal fats**	**Other sources**
Soybean (Glycine max)	Jatropha (Jatropha curcas)	Pork lard	Bacteria
Rapeseed	Mahua (Madhuca indica)	Beef tallow	Algae
Safflower	Pongamia (Pongamia pinnata)	Poultry fat	Microalgea
Rice bran oil	Camelina (Camelina sativa)	Fish oil	Terpenes
Barley	Karanja or	Chicken fat	
Sesame	Cumaru		
Groundnut	Cynara cardunculus		
Pumpkinseed (cucurbitae)	Abutilon muticum		
Wheat	Neem (Azadirachta indica)		
Corn	Jojoba (Simmondsia chinesis)		
Coconut	Passion seed		
Canola	Moringo (Moringa oleifera)		
Peanut	Tobacco seed		
Palm (Elaeis guineensis)	Rubber seed tree		
Sunflower	Tall (Carnegiea gigantean)		
Cottonseed	Castor oil (Ricinus communis)		
Poppyseed (Opium poppy)	Coriander		
Hazelnut	Coffee ground (Coffea arabica)		
Walnut	Wild mustard		
Almond	Nagchampa		
	Croton megalocarpus		
	pachira glabra		
	Aleurites moluccana		
	Terminalia belerica		

2.2.2 Biodiesel Production

There are four methods for biodiesel production. Those are blending, pyrolysis, micro emulsion and transestrefication. Although all these methods are used for production of biodiesel but each method have their own drawbacks.

2.2.2.1 Direct Mixing

In this method, vegetable oils are directly mixed with diesel. The disadvantages of vegetable oils as diesel fuel are:

- Higher viscosity
- Lower volatility
- The reactivity of unsaturated hydrocarbon chains

2.2.2.2 Pyrolysis (Thermal Cracking)

Pyrolysis is the processes that cause the break of the molecules by heating at high temperatures that is, by the heating of the substance in the absence of air or oxygen in temperatures. The disadvantages of this method are:

- The equipment for pyrolysis or thermal cracking is expensive
- The removal of the oxygen of the process reduces the benefits of an oxygenated fuel
- Not accepted from the point view of ash content, carbon residues and pouring point.

2.2.2.3 Micro *Emulsion*

Micro emulsification, practiced also to increase the cetane number and reduce the viscosity. Diesel fuel, vegetable oil, alcohol, surfactant and additive for increasing of certain number are mixed in suitable proportions and the mixture transformed, under vigorous stirring, into a micro emulsion with lower viscosity.

2.2.2.4 Transestrification Method

Many of researchers work on optimization of biodiesel production to get best fuel properties. Biodiesel is commonly produced by transesterification reaction in which the radical of an ester is substituted by the radical of an alcohol.

Biodiesel is usually prepared by the transesterification of the vegetable oil or animal fat feedstock and other non-edible raw materials such as frying oil, etc. There are several methods for conduct this transesterification reaction including the common batch process, heterogeneous catalysts, supercritical processes, ultrasonic methods, and even microwave methods. Chemically, transesterified biodiesel comprises a mix of mono-alkyl esters of long chain fatty acids (Atiya et al, 2017). The most common form uses methanol (converted to sodium methoxide) to produce methyl esters (commonly referred to as Fatty Acid Methyl Ester – FAME) as it is the inexpensive alcohol available, though ethanol can be used to produce an ethyl ester (commonly referred to as Fatty Acid Ethyl Ester – FAEE) biodiesel and higher alcohols such as isopropanol and butanol have also been used (Sintayehu et al, 2016). Using alcohols of higher molecular weights improves the cold flow properties of the resulting ester, at the cost of a less efficient transesterification reaction. A lipid transesterification production process is used to convert the base oil to the desired esters as shown in Figure 2.1 (Carlos et al, 2020). Any free fatty acids (FFAs) in the base oil are either converted to soap or removed from the process, or they are esterified (yielding more biodiesel) using an acidic catalyst. After this processing, unlike straight vegetable oil, biodiesel has combustion properties very similar to those of petroleum diesel, and can replace it in most current uses (Mohammad et al, 2016).

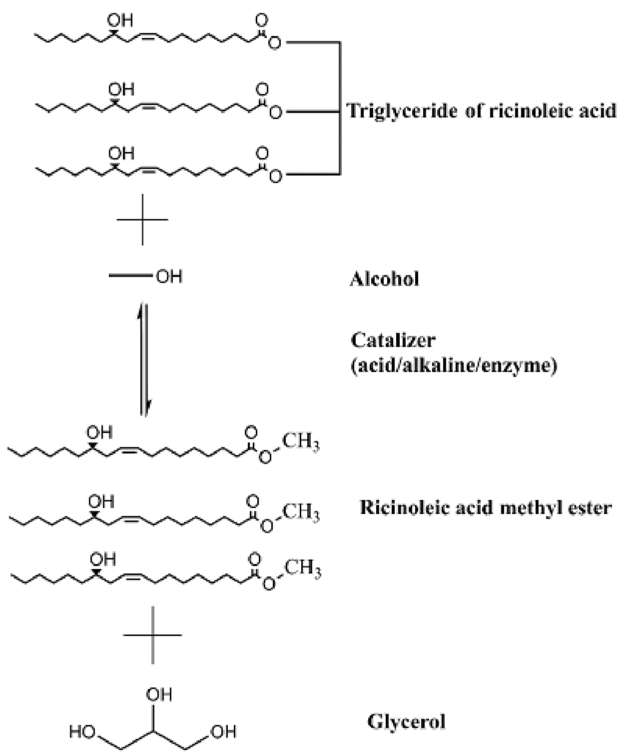

Figure 2.1 Transesterification reaction during biodiesel production using castor oil as feedstock, adapted from (Carlos et al, 2020).

2.2.3 Biodiesel Fuel Properties

The chemical structure of every fuel mainly determines their properties and combustion condition which persists to determine the engine thermal efficiencies and emission characteristics (Paul et al, 2016). Petroleum diesel contains only carbon and hydrogen atoms, which are arranged normal (straight chain) or branch chain structures as well as aromatics configuration. The straight chain structures are preferred for better ignition quality. Diesel fuel contained both saturated and unsaturated hydrocarbons, the latter are not presented in considerable amounts to prevent fuel oxidation problem. Petroleum-derived diesel is composed of 75% saturated hydrocarbons (primarily paraffin's including n-, iso- and cyclo- paraffins), and 25% aromatic hydrocarbons (including naphthalene's and benzenes) .

Biodiesel is defined as mono-alkyl esters of fatty acids derived from trans-esterification of agricultural lipids with short-chain alcohol. Variation in the chemical nature of biodiesel and conventional diesel fuel caused differences in their basic properties, which affect engine

Biodiesel has promising lubricating properties and cetane ratings compared to low sulfur diesel fuels. Fuels with higher lubricity may increase the usable life of high-pressure fuel injection equipment that relies on the fuel for its lubrication.

The calorific value of biodiesel is about 37.27 MJ/kg. This is 9% lower than regular Number 2 petro diesel. Variations in biodiesel energy density are more dependent on the feedstock used than the production process. Still, these variations are less than for petro diesel (Keera et.al, 2018) (Osman et al, 2015) (Shojaeefard et al, 2013)

The color of biodiesel ranges from golden to dark brown, depending on the production method. It is slightly miscible with water, has a high boiling point and low vapor pressure. The flash point of biodiesel exceeds 130°C (266°F), significantly higher than that of petroleum diesel which may be as low as 52°C (126°F (Osman et al, 2015) (Keera et al, 2018) (Shojaeefard et al, 2013).

The power output of biodiesel depends on its blend, quality, and load conditions under which the fuel is burnt. The thermal efficiency for example of B100 as compared to B20 will vary due to the differing energy content of the various blends. Thermal efficiency of a fuel is based in part on fuel characteristics such as: viscosity, specific density, and flash point; these characteristics will change as the blends as well as the quality of biodiesel varies (Mohammad et al, 2016).

Several authors have examined the physical properties of COME it, and have come up with contradicting results. Jaime et al. (Jaime et al, 2015) reported of excellent OS, low temperature properties and poor CN.

2.2.3.1 Fuel viscosity

One of the main concerns regarding biodiesel is its viscosity. The viscosity of diesel must be high enough to provide sufficient lubrication for the engine parts but low enough to flow at operational temperature. High viscosity can plug the fuel filter and injection system in engines. Vegetable oil is composed of lipids with long chains of hydrocarbons, to reduce its viscosity the lipids are broken down into smaller molecules of esters. This is done by converting vegetable oil and animal fats into alkyl esters using transesterification to reduce their viscosity. Nevertheless, biodiesel viscosity remains higher than that of diesel, and the engine may not be able to use the fuel at low temperatures due to the slow flow through the fuel filter.

The exceptionally high kinematic viscosity of COME, exceeding by far the international standard upper limit has been well established in the past many authors (Atiya et al, 2017). Many authors suggests tranesterification and blending biodiesel with petro diesel can reduce the extremely high viscosity of biodiesel (Mohammad et al, 2016). The dissolution of biodiesel in in petro diesel minimizes intermolecular interactions responsible for kinematic viscosity. Table 2.2 shows the biodiesel specifications according to EN 14214 and ASTM D6751 standards and the was captred from (Chevron et al, 2014).

Table 2.2 Biodiesel specifications according to EN14214, and ASTMD6751 standards (Chevronet et al, 2014)

Property	**Test methods**	**Grade S15**	**Grade S500**
Calcium and Magnesium, Combined, ppm (µg/g), max	EN 14538	5	5
Flash point (Closed Cup), °C (°F), min	D 93	93 (199)	93 (199)
Alcohol Content One of the following must be met: 1. Methanol content, max 2. Flash point, min	 EN 14110 D 93	 0.2 130	 0.2 130
Water and Sediment, % vol, max	D 2709	0.050	0.050

Kinematic Viscosity, 40°C (104°F), mm^2/sec	D 445	1.9 – 6.0	1.9 – 6.0
Sulfated Ash, % mass, max	D 874	0.020	0.020
Sulfur, % mass (ppm), max	D 5453	0.0015 (15)	0.05 (500)
Copper Strip Corrosion, max	D 130	No. 3	No. 3
Cetane Number, min	D 613	47	47
Cloud Point, °C	D 2500	Report	Report
Carbon Residue, % mass, max	D 4530	0.050	0.050
Acid Number, mg KOH/g,Max	D 664	0.50	0.50
Free Glycerin, % mass	D 6584	0.020	0.020
Total Glycerin, % mass	D 6584	0.240	0.240
Phosphorous Content, % mass, max	D 4951	0.001	0.001
Distillation Temperature, Atmospheric Equivalent Temperature, 90% Recovered, °C (°F), max	D 1160	360 (680)	360 (680)
Sodium and Potassium, combined ppm (µg/g), max	EN 14538	5	5
Oxidation Stability, hours, min	EN 14112	3	3

2.2.3.2 Flash Point

The flash point of a fuel is the lowest temperatures at which the fuel can be ignite when exposed to a flame or spark. The flash point of biodiesel is higher than the petroleum based diesel fuel. The flash point biodiesel blends is dependent on the flash the flashpoint of base diesel fuel used, and increase with percentage of biodiesel in the blend. Thus in storage, biodiesel and its blends are safer than conventional diesel.

2.2.3.3 Pour Point

The pour point of a fuel is the lowest temperature at which it will pour or flow when cooled under prescribed conditions. It is a very rough indication of the lowest temperature at which fuel oil is readily pumpable.

2.2.3.4 Calorific Value

The calorific value is the measurement of heat energy produced and is measured either as gross calorific value or net calorific value. The difference being the latent heat of condensation of the water vapor produced during the combustion process. Gross calorific value assumes all vapor produced during the combustion process is fully condensed. Net calorific value assumes the water leaves with the combustion products without fully being condensed. Fuels should be compared based on the net calorific value.

2.2.3.5 Lubricity

Lubricity is an essential property of the fuel for proper functioning of engine components such as fuel pumps and injectors. Due to strict environmental regulations, sulfur content in petrodiesel has been significantly reduced over the past few years. This has led to reduced fuel lubricity, which can cause severe damage to the engine (Lalit Prasad, 2012). Many researchers reported on the inherently greater lubricity of biodiesel, compared to petro diesel, even at low blend levels. Hydroxylated fatty esters in particular, such as ricinoleic acid, were found to exhibit improved lubricity compared to other vegetable oil ester (Lalit Prasad, 2012). Kinney and Clemente (Kinney et al, 2009) even suggested using genetic engineering to modify soybean oil to include 10-20% ricinoleic acid for improved lubricity of the fuel.

2.3 Effect of Magnetism on Fuel Molecules

Fuel molecule consists of a number of atoms made up of number of nucleus and electrons, which orbit their nucleus. Magnetic movements already exist in their molecules and they therefore already have positive and negative electrical charges. Fuel mainly consists of hydrocarbon and when fuel flows through a magnetic field, the hydrocarbon change their orientation and molecules of hydrocarbon change their configuration. At the same time inter molecular force is considerably reduced or depressed. These mechanisms are believed to help disperse oil particles and to become finely divided as shon in Figure 2.2. This has the effect of ensuring that fuel actively interlocks with oxygen producing a more complete burn in the combustion chamber. The result is better fuel economy and reduction in hydrocarbons, carbon monoxide and oxides of nitrogen that are emitted though exhaust (Farrag et al, 2010).

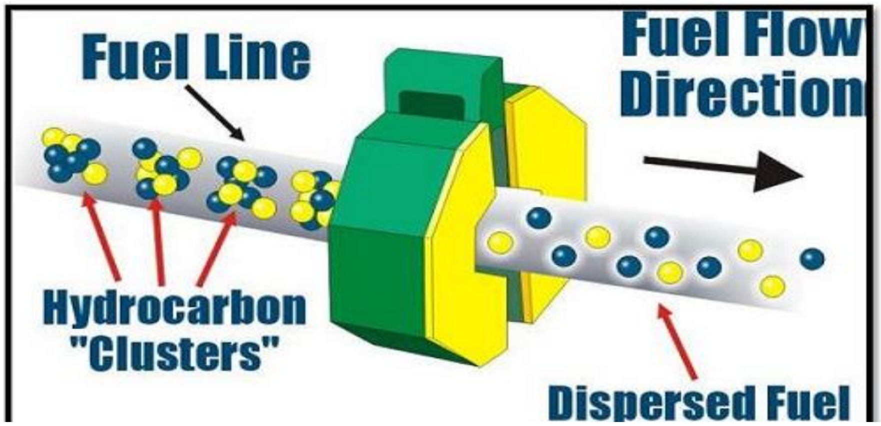

Figure 2.2 Changing in Fuel after Passing through Magnetic Field adapted from (Komal et.al, 2016)

2.3.1 Working Principle

With respect to previous information provided it is clear that application of magnetic field over the fuel results into certain change in orientation of molecules which promotes energy efficient oxygen supply for complete combustion to occur. It was known that the molecules are bonded together due to nuclear forces of attraction between the atoms. This forces are uneven, hence they have misalignment in their structure which provides varying spaces for oxygen to penetrate for successful mixing of air and fuel leading to complete combustion. This will reduce the formation of harmful effluents like CO, NO_x, CO_2, and HC. The changes that occur inside molecules are broadly described below using Ortho and Para molecule formation and their alignment structure. These molecules are classified based on the spin of their nuclei. Hydrogen isomers are classified on same base as ortho hydrogen and Para hydrogen.

2.3.1.1 Para Molecules

In Para Hydrogen molecule the rotation spin of nucleus is anti-parallel i.e. the spin of one atom is opposite to other atom which makes it diamagnetic in nature. It is a general type of molecule at room temperature. It is less stable than the ortho molecules. These molecules are preferred for carrying magnetic field testing.

2.3.1.2 Ortho Molecules

In Ortho molecule the spin of rotation of nucleus is parallel, contradictory to that in Para hydrogen molecule. This makes molecule more uniformly aligned and provides more space for oxygen penetration. Para molecules are converted into ortho using strong magnetic field generally more than 2000 Gauss.

2.3.2 Effects of Biodiesel and Fuel Magnetizing on Engine Performance and Emissions Characteristics

2.3.2.1 Brake Power

Properties of biodiesel especially in heating values, viscosity and lubricity, have an important effect on brake power of the engine. (Parvaneh et al, 2017) found that the reduction of brake power to be 1.06%, 2.57%, 4.8% and 4.98% for COB5, COB10, COB20 and COB30 with respect to diesel at load of 25% respectively. The result of (Ismail et.al, 2014) experiment also shows the decrement of brake power of the engine for COB10, COB20, COB30, COB40 and COB50 by 1.17%, 3.00%, 3.00%, 4.91% and 4.91% respectively. On the other hand (Panwar et.al, 2009) studied that the brake power developed by the engine on different load conditions were increased for all blends of biodiesel. At maximum load they found the COB5, COB10 and COB20 developed 1.5%, 1.76% and 0.75% more brake power than COB0. This is achieved due the availability of oxygen in biodiesel, which leads it to complete combustion.

In general, the authors result shows that even though the energy contents of biodiesel are lower than that of convectional diesel fuels, the brake power of the engine can be increased by studying the way to achieve optimum complete combustion.

2.3.2.2 BSFC

Fuel properties like blend density and lower heating value powerfully dominate the fuel consumption in terms of BSFC. The lower heating value and higher density of biodiesel blended fuel reduce the flame speed for combustion which in turn affects the pressure and acting on the piston. (Swaroopa et al, 2017) Found that, at maximum load, the BSFC is increased by 8% and 18% for COME% and COME15 respectively, While 3% decrement was obtained for COME10 with respect to diesel. Many authors agreed on the increment of BSFC as the ratio of blend of biodiesel increases (Panwar et al, 2009) (Parvaneh et al, 2017).

2.3.2.3 Brake Thermal Efficiency

The brake thermal efficiency (BTE) can be described as the value of the output work divided by the input energy amount in the internal combustion engines. The BTE of CI engines is affected by air-fuel ratio, fuel properties, combustion process, and compression ratio (Murat Kadir Yesilyurt et.al, 2020). The brake thermal efficiency tested engine by (Babu D et.al, 2017) were increased up to 750W of the engine load and then starts decreasing when further increasing the load due to higher BSFC at higher load and incomplete combustion. With sluggish combustion and lower heat release rate of COME, the peak pressure is very low compared to diesel operation (Prakash et.al, 2018).

2.3.2.4 Heat Release

Due to the high viscosity of COME and subsequently with the reduction in fuel air mixing rates, less fuel is prepared for rapid combustion with COME. Therefore, more burning takes place in the diffusion phase rather than in the premixed phase with COME. Delayed combustion and higher combustion rates during the later stages with COME leads to higher exhaust temperature and lower brake thermal efficiency.

2.3.2.5 Ignition Delay

The ignition delay in a diesel engine was defined as the time interval between the start of injection and the start of combustion. The start of injection is usually taken as the time when the injector needle lifts off its seat (determine by a needle –lift indicator). Ignition delay for COME is higher for all loads, compared to diesel because of very high viscosity, low volatility and high density of COME. This contributes to poor atomization and fuel air mixture preparation, thereby increasing the ignition delay.

2.3.2.6 Emission Analysis

Nitric Oxide Emission

Specific NO_x emission is very low for net COME when compared to diesel operation as stated by (Prakash et al, 2018). Formation of NO_x depends on in-cylinder temperature and oxygen content in the fuel. With COME, premixed combustion is very slow due to poor mixture formation during ignition delay period. As a result, the heat released during the premixed combustion phase is less, which results in lower combustion temperature and lowers NO_x emission.

Carbon Monoxide

Diesel engine operating on neat COME emits very high CO emissions compared to diesel fuel operation, which is nearly six times higher than base engine CO emission according to (Prakash et al, 2018). This is mainly attributed to the sluggish and incomplete combustion because of poor volatility and viscosity of COME which causes very less atomization, vaporization and non-uniform air fuel mixture preparation.

Hydrocarbon Emission

(Prakash et al, 2018) reported as COME results in higher HC emissions compared to diesel. Very high viscosity and density of COME causes poor atomization and non-uniform mixing of air with bigger size fuel particles. But (Andre et al, 2017) reported that COME has lower HC emission at high load due its higher contents of O_2 and at lower load the difficulties in atomization of COME leads it to have higher HC emissions.

2.4 Research Gap

From the literatures review it is found that the properties of biodiesel fuel can be highly depend on the raw materials, method of oil extraction, temperature at which transesterification takes place, the ratio of oil to catalyst and alcohol. The most detrimental effect, based on intermolecular interactions imparted by the hydroxyl moiety, was found on KV and DT, which exceeded by far the international standard limits. Different researchers have been tried to reduce the viscosity of biodiesel by optimizing the transesterification reaction and by lower percentage of blend with conventional diesel fuel. On the other hand various researches showed that the magnetic force application in the fuel line can improve the combustion by increasing the fuel ionization and they are conducted for biodiesel produced from different sources. But no one has been studied the effect of fuel magnetization for castor oil biodiesel fuel.

In this work two possible solutions can be employed for increasing the range of feed stocks for the biodiesel industry by also including COME. The first solution involves blending COME in petro diesel. The second solution is applying magnetic force in the fuel inlet line to increase the combustion of the fuel in the combustion chamber. In the present work effect of magnet on engine performance and emission characteristics which is fueled with castor oil biodiesel and petro diesel blend was studied.

CHAPTER THREE

MATERIALS AND METHODOLOGY

Introduction

The castor seed preparation for oil, biodiesel production, biodiesel blend and property tests, the effect of COME and magnet on the diesel engine performance and emission has been performed in this work. The procedures for each activities has been discussed in this chapter.

The overall steps of the work is given in the Figure 3.1.

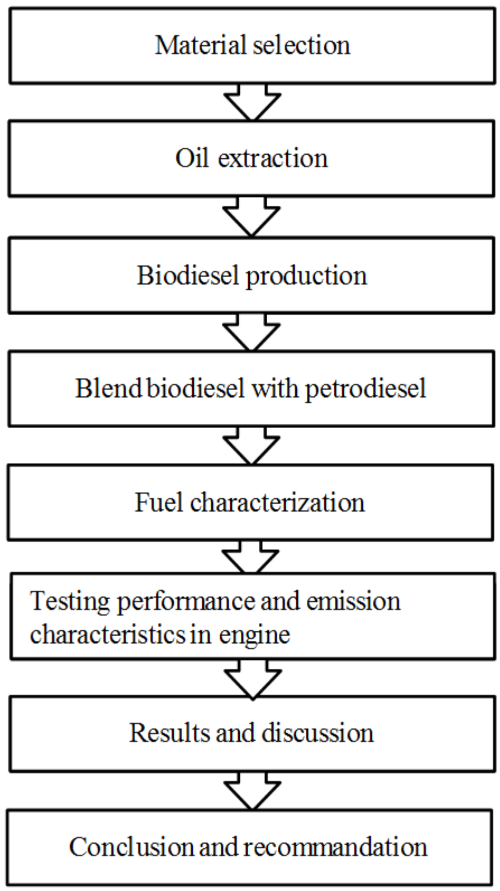

Figure 3.1 Work Flow

3.1 Required Materials and Equipments

3.1.1 Materials

For the production of the biodiesel and test it in engine the following consumables are used.

***Castor Seed*:** Caster oil was selected for biodiesel production, because it is nonedible and posses higher oxygen content.

Methanol: Methanol and ethanol are mostly used alcohol for transesterification and in this work methanol was used because it is the least expensive alcohol and it shows chemical advantages such as its shorter chain and its polar nature.

***NaOH*:** For the transesterification reaction a catalyst like NaOH and KOH are mostly used. For this work NaOH tablet which is easily soluble in methanol was selected as a catalyst due to its cheapest cost when compared to KOH.

***Nedium Magnet*:** For fuel magnetizing a permanent magnets like nedium and ferrite are used. In this work nedium magnet, which was shown in Figure 3.2, was selected for its higher strength field and also it is a permanent magnet which is mostly used magnet for fuel magnetizing.

Figure 3.2 Permanent Nedium Magnet

Diesel Fuel: Diesel fuel is used for blending it with castor oil biodiesel and test it in diesel engine.

3.1.2 Equipments

The equipments used in this work are given in table 3.1.

Table 3.1 Equipments required for this work

No	Equipment	Purpose	Quantity
1	Mechanical Press	For oil extraction	1
3	Magnetic Stirrer with Hot Plate	For transesterification reaction	1
4	Magnetic Stir Bar	For stirring during the reaction	1
5	Measuring Cylinder	To measure oil and methanol volume	2
6	Electronic digital weighting scale	To measure weight of NaOH	1
7	Aluminum foil	To cover a beaker during the reaction	
8	Separator Funnel	To separate glycerol from COME	2
9	Viscometer	To measure viscosity of fuel	1
10	Dynamometer	To test fuels on engine	1
11	Exhaust Gas Analyzer	To measure the exhaust gas emissions	1

3.2 Biodiesel Production by Transesterification

The steps followed to prepare biodiesel in the present work has been given in the Figure 3.3

3.2.1. Seed Preparation

The castor seeds were bought from local market Ehel Berenda, Addis Ababa, Ethiopia. Then dried in the sun, cleaned and made ready for oil extraction as shown in Figure 3.4.

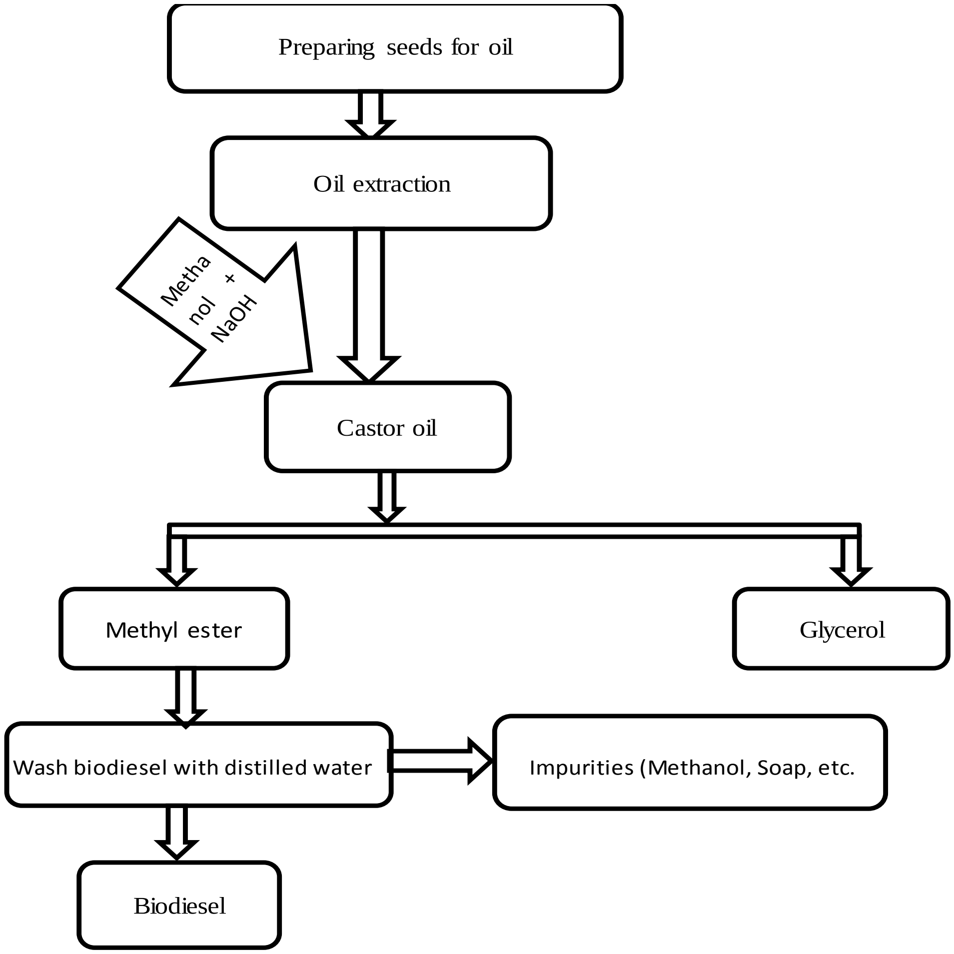

Figure 3.3 Biodiesel production steps

Figure 3.4 Castor seed Prepared for oil extraction

3.2.2. Oil Extraction

The prepared pure castor seed goes for oil extraction using mechanical press. The oil is extracted at Etalbar in Figa, Addis Ababa, Ethiopia. The steps followed for the oil extraction are given as follows;-

- The machine was started and heated at 40^0C for 10minutes
- The seed was slowly added manually on the top
- The extracted oil was stored in cylinder
- The oil was then washed with hot water of 60^0C to remove impurities
- The oil was heated at 120^0C for 1h to remove water from the oil.

The extracted, drained and prepared for the COME conversion oil was given in Figure 3.5.

Figure 3.5 Extracted Castor Oil

3 .2.3 Biodiesel Production by Transesterification

Titration

To decide whether a single or two-step transesterification is required to produce biodiesel, first it is necessary to determine the acid value of the oil, so that if the value is less than 2 a single stage transesterification can be used for the biodiesel production. To determine the free fatty acid of the oil the process called titration was used. The castor oil was first mixed with methanol and then the solution of NaOH and distilled water id added to the solution of Oil and methanol until the color of the solution was changed to pink. Then the FFA was calculated as:-

$$\text{Acid number} = \frac{\mathbf{39.997 \times V \times N}}{\textbf{Weight of the sample in gm}} \quad \text{....................(3.1)}$$

Where, V is Volume of NaOH consumed and

N is Normality of NaOH = 0.1

$$\text{Acid number} = \frac{39.997 \times 2.8 \times 0.1}{6} = 1.87$$

Thus, since the value of acid is less than two a single stage transesterification can be used for biodiesel production. Transesterification, which is also called alcoholics, is a process of substitution of the radical of an ester by the radical of one alcohol as shown in Figure 3.6.

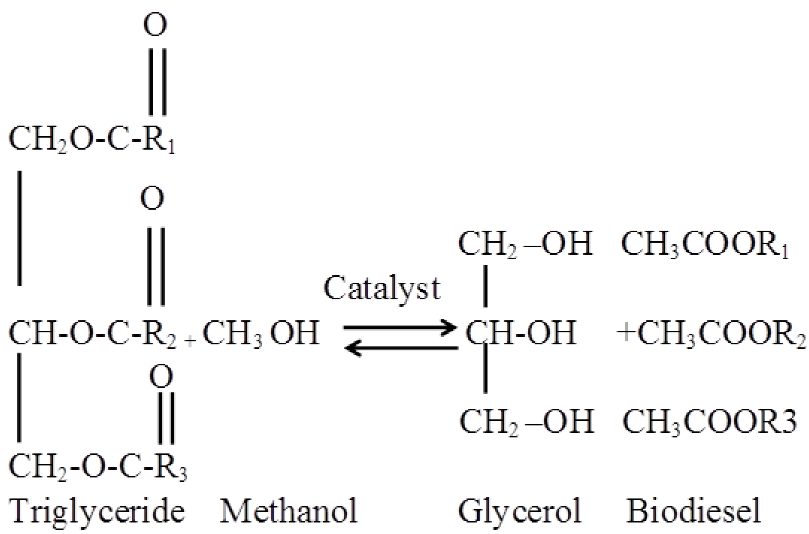

Figure 3.6 Transesterification Reaction

The transesterification reaction is mainly affected by four main factors. Those are; reaction time, reaction temperature, catalyst and oil to methanol ratio. These factors affect the quality of biodiesel produced as well its conversion yields. In this work the reactants ratios are followed as (Mithun Das, 2016). 25% of Methanol (V/V of oil) and 1.75% of NaOH (W/W of oil) has been used for the transesterification reaction.

The reaction was allowed to take place for 1h at 50^0C. Accordingly, 600ml of castor oil is added to a 1000ml beaker and heated at 50^0C for 1 hour. In the meantime 5.75gm of NaOH is dissolved in 200ml of methanol to maintain the catalytic activity as shown in Figure 3.7a. The catalyst solution is then added slowly to the preheated oil and allowed to react for 1 hour at 50^0C. On the completion of the reaction, the mixture is allowed to settle under gravity in the separator funnel at room temperature as shown in Figure 3.8. The glycerin and other impurities are removed from biodiesel by opening the tap provided at the bottom of separator funnel.

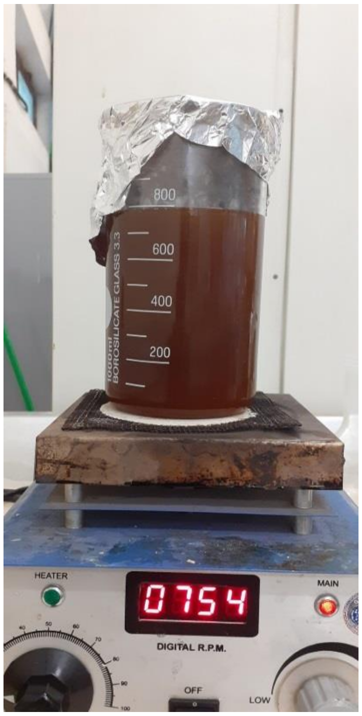

Figure 3.7 a) Dissolving NaOH in Methanol, b) Transesterification reaction on magnetic stirrer with hot plate

Generally the steps which are followed to produce the biodiesel were given as follows:-

1. Heat castor oil to 60^0C for 30 minutes.
2. Dissolve NaOH into methanol
3. Add the NaOH and methanol solution to the preheated castor oil on the magnetic stirrer with hot plate
4. Allow the reaction to take place for 1h.
5. Transfer the mixture to separator funnel and allow it to stand under gravity for 12h.

6. Remove the glycerol from the mixture
7. Wash the crude biodiesel until pure biodiesel was found
8. Heat the biodiesel to 120^0C to remove water content as shown in Figure 3.11a.

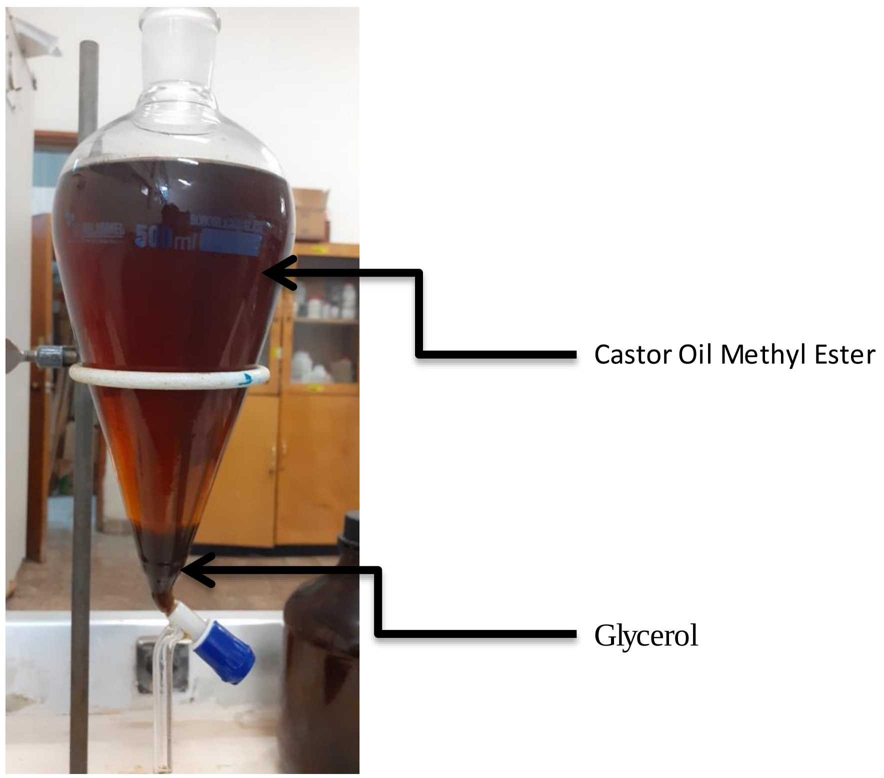

Figure 3.8 Separating Castor Methyl Easter and glycerol under gravity in separator funnel

The crude biodiesel, which was shown in Figure 3.9, was washed with distilled water, which is heated to 50^0C, to remove residuals like methanol, soap. The same process was repeated to produce more biodiesel.

Figure 3.9 Crude Biodiesel

Figure 3.10 a) First round washed biodiesel, b) Final round washed biodiesel

Figure 3.11 a) Drying biodiesel b) Pure Biodiesel

Figure 3.12 Comparison of the samples

3.2.4 Biodiesel Characterization and Blending with Petro diesel

After producing and blending with diesel the pure and its blend of B20 fuels are characterized before going to test it in engine. Among fuel properties the density and viscosity are measured and the rest of properties like pour point, flash point, calorific value, iodine value and FFA are not measured due their higher cost requirement for characterization. The viscosity of the fuel for B100 and B20 os samples given in the Figure 3.12 was measured at Materials Engineering department lab. The viscosity of pure biodiesel was found to be 12mm^2/s and that of blended B20 is 3.9 mm^2/s.

Figure 3.13 a) Measuring viscosity of biodiesel b) measuring viscosity of B20

3.3 Selection of Magnet and its Installation Location

Using permanent magnet instead of electromagnet was suggested, due the fact that the energy required for generating the magnetic field was more than the fuel energy saved due to magnetic fuel conditioning. A permanent magnet which was made from neodymium has been used in this work. The magnetic field strength depends on the material of fuel line pipe. But the optimum position for installing the permanent magnet is exactly on fuel line which is nonmagnetic materials (Shweta Jain, 2012).

3.3.1 Magnetic Field

Magnetic field can be provided by two methods. The first one is by using electromagnets and the second is by permanent magnets. In this experiment, neodymium magnet was used as permanent magnet to provide magnetic field. Permanent magnets are basically classified as Neodymium magnets and Ferrite Magnets.

Neodymium Magnets (Nd_2Fe_{14}) are the tetragonal crystalline structure and these are most widely used type of rare earth magnets. These are made from the alloy of neodymium, iron and boron and are considered to be the strongest magnet among other permanent magnet.

Pre-Combustion

Fuels are having hydrocarbon. They are in a covalent bond in crystal structure. In that, hydrogen has a di - pole moment. Hydrogen can occur in two isometric forms.

These are: 1) Para State

2) Ortho State

Electrons have ability to store energy with in itself. Similar to fly wheel called spin (+1/2, -1/2). Para state has opposite spin and Ortho state had same spin. So Para state is less reactive whereas ortho state is more reactive. Initially hydro-carbons present in the fuel are in Para state which has more intermolecular force of attraction. So fuel particles are not actively interlocks with oxygen which leads to incomplete combustion there should be a good interaction between the oxygen and hydro-carbons. To attain good interaction the Para state of hydro-carbons are changed to ortho state by applying the magnetic field around the fuel line before entering the combustion chamber.

Reaction with Magnetic Field

When spin provides small amount of magnetic field, electrons absorbs the energy and properties will change which is based on the following theories (Shweta Jain, 2012).

1) Chemistry theory (Covalent bond {C=H }bond)
2) Physics theory (Barnett effect)
3) Math's theory (Quantum theory)

1. **Chemistry Theory**

Each electron has two moments; spin moment and orbital moment which maintains uniform fuel structure. Figure 3.14 shows molecules of fuel having a tendency to attract towards nucleus, due to which intermolecular force of attraction increases and thus fuel particle are not actively interlocked with oxygen during combustion and some un-burn fuel goes into exhaust and thereby causing incomplete combustion. In applying magnetic field around fuel inlet line, the intermolecular force of attraction on nucleus has been reduced, which results in better combustion.

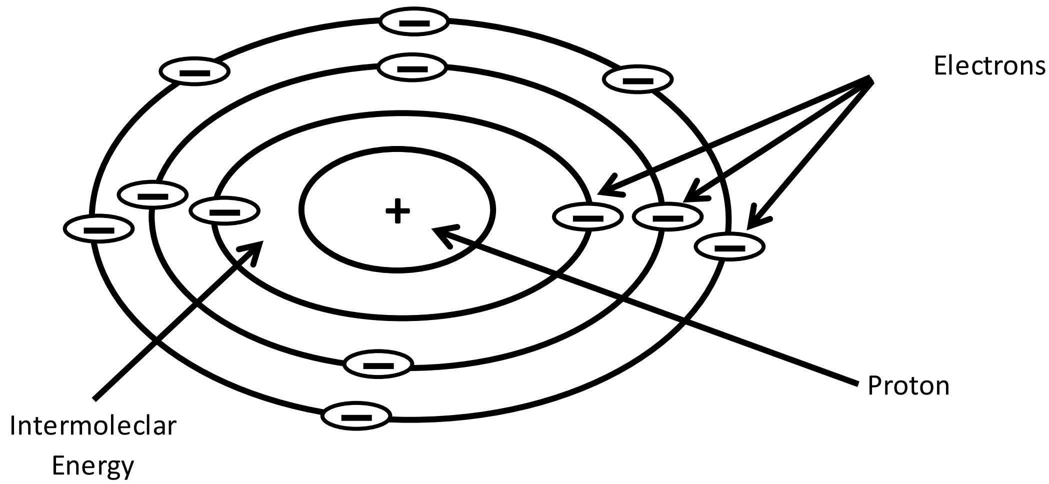

Figure 3.14 Energy levels of molecules

2. **Physics Theory**

Due to magnetic effect on molecules, spinning electrons will absorb the energy and finally flip into alignment. Because of that cluster structure of fuel breaks i.e. bonds will break into fine particles. Now, this fine particles (C and H) having magnetic influence, which tend to adhere more oxygen electrons i.e. extra oxidation is done and ultimately complete combustion at its optimum value is obtained, hence pollution will reduce (Shweta et al, 2012).

3. **Math's theory**

   Quantum (Math's) theory is used for analyzing the above effects which are occurred in covalent bond and Barnett theory.

3.4 Experimental Set Up

The experimental investigation for mineral diesel, B20 without magnet and B20 with magnet was conducted on a single cylinder four stroke diesel engine and the performance and emissions of the engine was analyzed. The overhall experimental setup is shown Figure 3.15, schematically. In Figure 3.17, the expremental set up was given and Figure 3.18 shows the location of permanent magnet.

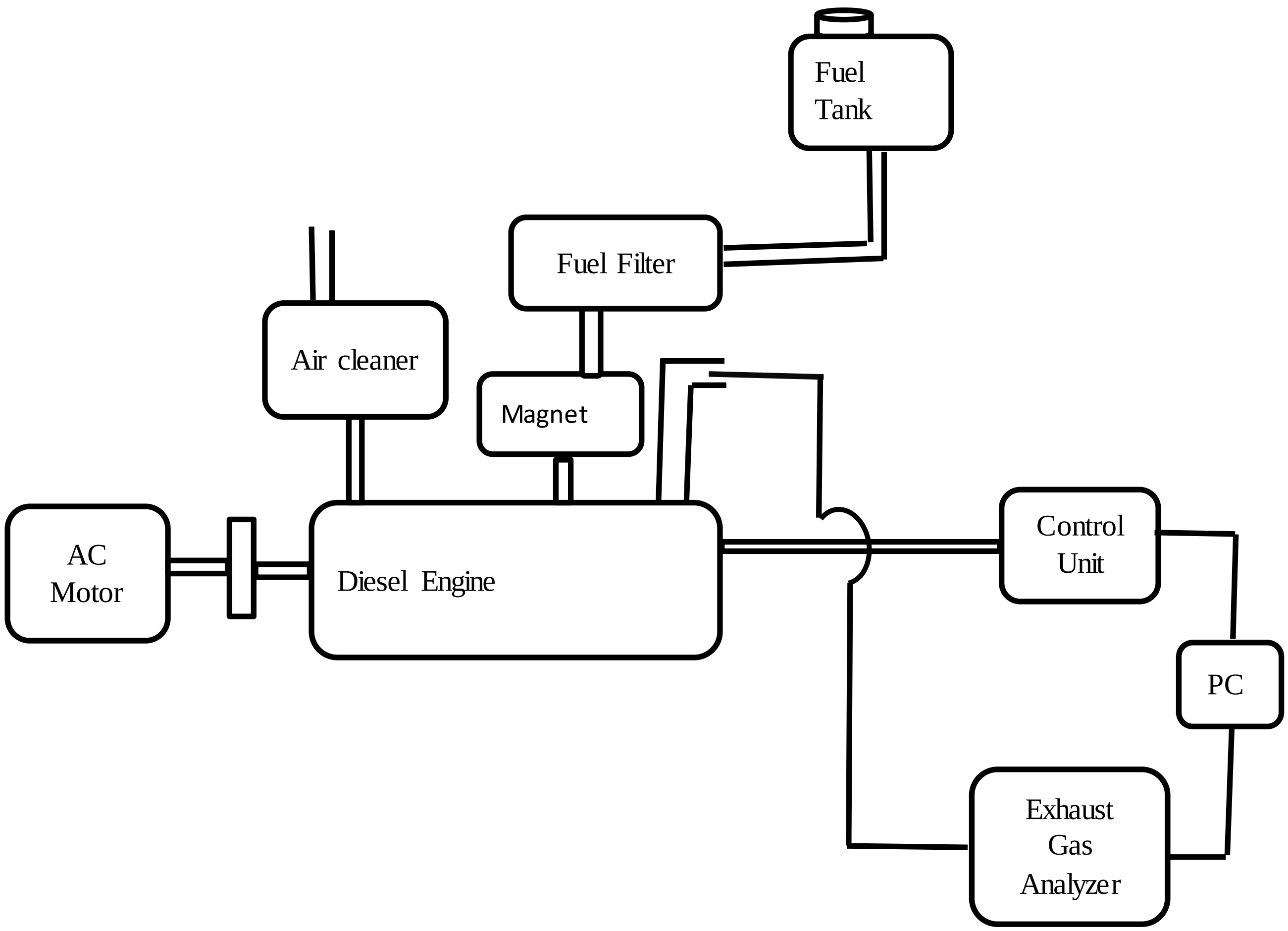

Figure 3.15 Experimental Schematic Diagram

Equipment's Used During the test

In this work the produced biodiesel and its blends were tested in Addis Ababa Science and Technology University on TBMC3-03 Computer Controlled Test bench with 4-stroke, single cylinder engine to examine its effect on the engine performance and exhaust emissions. The specifications of engine used for this purpose are given in table 3.2. The test bench measures the power output, volume flow rate of fuel, exhaust gas temperature, torque, mass flow rate of air and speed of the engine by varying the load on the engine. The test bench consists of four main elements; Asynchronous motor, an air cooled diesel engine (TBMC3-03), SCANDA software control system and exhaust gas analyzer (TBMC_AGE) as shown in Figure 3.17.

Table 3.2 Engine Specification

Specifications	
Type	4-stroke, single cylinder
Displacement	127cc
Bore x Stroke	69mmx60mm
Max. Horsepower	4.2HP/3.1kw/3600rpm
Max. Torque	7.7N.m(6.8)/2800rpm
Compression ratio	21:1
Cooling system	Air cooled
Air cleaner	Dual element type
Oil capacity	0.6L
Starting system	Recoil or electric starter
Stopping system	Ignition primary circuit ground
Fuel capacity	2.5L
Carton Dimensions (LxWxH)	390mmx340mmx350mm
Net/Gross weight (approx.)	13.3kg/14.4kg

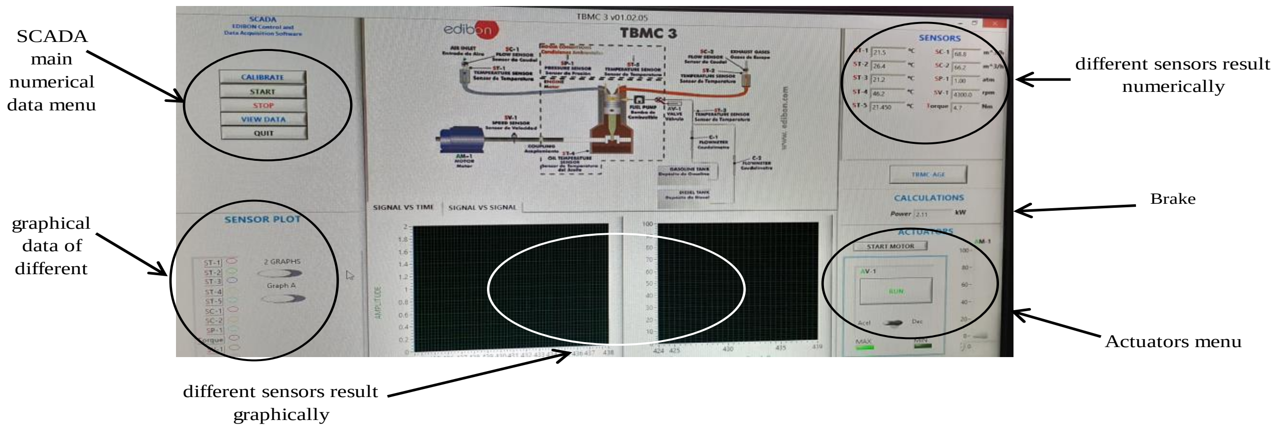

Figure 3.16 TBMC computer main screen

Figure 3.17 Experimental set up

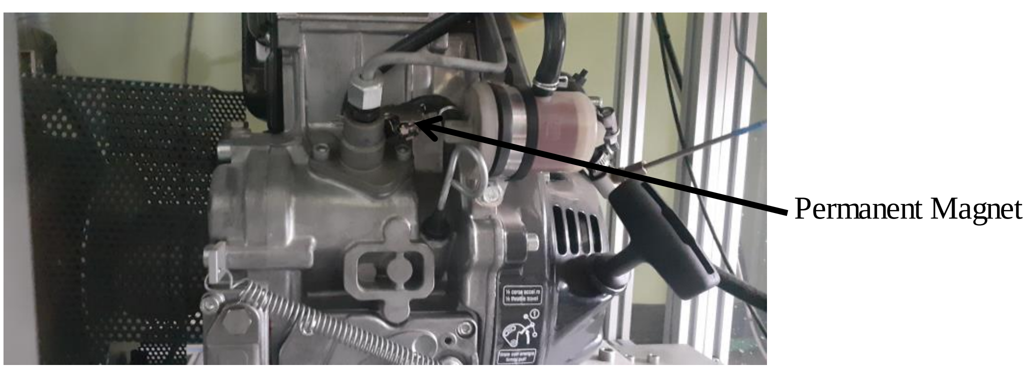

Figure 3.18 Experimental set up with magnet installed in fuel line

Steps for Experimental Tests

To conduct the tests, the foolowing procedures were followed.

1. Inspect necessary engine components and check lubricants
2. Connect electrical connection and start the electrical power
3. Add diesel fuel in the fuel tank
4. Power on the computer, start the engine, allowed it to run at idle condition for 10 minutes, so that it can reach operational condition
5. Conduct the tests for diesel fuel by varying the engine speed, and record all necessary datas for all engine speed
6. After completing the first test, change the fuel to B20, and repeat steps 3-5 for B20.
7. Finally install the magnet in the fuel line and repeat steps 3-5 for B20.

3.4.1 Brake Power

Power is defined as the rate of work of the engine. The brake power was usually measured by attaching a power absorption device to the drive shaft of the engine. The brake power of engine at different operating conditions was determined as;

$$\mathbf{P_b = \boldsymbol{T}_b \times 2\pi N} \quad \text{...(3.2)}$$

Where, P_b is Brake power in kW

T_b is brake torque in N.m

N is Engine speed in RPM

3.4.2 Brake Torque

Torque is a good indicator of an engine's ability to do work (Pullkrabek). Torque is defined force acting at a moment distance and has units of N-m.

$$\mathbf{T_b = \frac{60P_b}{2\pi N}} \quad \text{...(3.3)}$$

Where, T_b is engine brake torque in N.m

P_b is Brake power in kW

N is engine speed in RPM

3.4.3 Mass of Fuel Consumption

The fuel consumption of an engine was measured by determining the time required for consumption of a given volume of fuel. The mass of fuel consumed by the engine at different operating conditions was determined using the equation given below:

$$\mathbf{m_f = V_f \times \rho_f} \quad \text{.......} \quad (3.4)$$

Where, V_f is the volume flow rate of the fuel in ml/min

ρ_f is density of the fuel in g/ml

3.4.4 Brake Specific Fuel Consumption

Brake specific fuel consumption is defined as the ratio of mass fuel flow rate to the brake power.

$$\text{BSFC} = \frac{\mathbf{m_f \times 3600}}{\mathbf{P_b}} \quad \text{.......} \quad (3.5)$$

Where, BSFC is brake specific fuel consumption in kg/kW.h

m_f is mass of fuel consumed in kg/s

P_b is brake power in kW

Exhaust gas analyzer specification

Different emissions like CO_2, CO, HC and O_2 are measured by using TBMC-AGE Exhaust gas analyzer. The measurements and technical specification of the equipment was given in table 3.3

Table 3.3 Exhaust Gas Analyzer Specification

Measurements	
Emissions	Unit
Carbon dioxide (CO_2)	%
Carbon monoxide (CO)	%
Hydrocarbons (HC)	Ppm
Oxygen (O_2)	%
Technical Specification	
Working temperature	2 ^{0}C to 40 ^{0}C
Pressure	800-1060bar
Dimensions	600 x 200 x 300 mm
Weight	5kg approx.

CHAPTER FOUR

RESULT AND DISCUSSION

In this work different activities were performed like production of biodiesel, measuring the properties of biodiesel, and testing the performance and emission characteristics of biodiesel in diesel engine. The influence of magnetization of fuel on the performance and emission of the engine was also studied in this work. The engine performance tests were conducted with fuel with magnetization and fuel without magnetization. The results found in all the tests are discussed one by one in next subtitles.

4.1 Biodiesel Production

The properties and conversion rate of biodiesel is mainly based on the reaction time, temperature, catalyst and oil to alcohol ratio. In this work the optimum condition as stated by (Mithun et al, 2016) was used and the conversion yield of 88.75% was obtained. The density and viscosity of the biodiesel and its blend were tested in Adama Science and Technology university Material Science department laboratoryand given in table 4.1. From the table it was observed that the viscosity of pure biodiesel is very high and it is beyond ASTM D6751 standard. But when it was blended with petroldiesel, it fulfills the ASTM D6751 standard. Other fuel properties such as, pour point, cloud point, FFA, flash point are not tested in this work due to equipment limitation and higher cost to test them.

Table 4.1 Fuel Properties

Properties	**B100**	**B20**
Density @ 25^0C kg/m^3)	904	840
Kinematic Viscosity @ 25^0C (mm^2/s)	12	3.9

4.2 Engine Performance

4.2.1 Engine Brake Power

The brake power is defined as the rate at which work is done by the engine. The average percentage in engine brake power values change with respect to engine speed for all tests as recorded in table 4.2. Properties of COME, especially heating value, viscosity and lubricity, have a significant effect on brake power of the engine. As observed in the test, the brake power of B20 is lower than that of diesel fuel while, B20 + magnet has higher than that of B20. The reason for increase in brake power for magnetized B20 is due to the complete combustion of the fuel, in which higher energy conversion is found. From Figure 4.1, it is observed that magnetization has a substantial effect on fuel ionization which leads to have complete combustion and thus have higher brake power when compared to B20.

The brake power for all tests shows increment until the maximum brake power is reached at 3600 rpm, which are 2.16kW, 2.04kW, and 2.12kW for B0, B20 and B20 + magnet respectively. From these data the engine brake power is dropped by 5.8% for B20 when compared to mineral diesel. This happened due to the lower calorific values of COME and other properties like higher viscosity of COME, which leads to late fuel ionization and thus has higher incomplete combustion. Later by adding the magnet in fuel line for B20, the brake power has seen raised by 3.9%. This clearly shows as magnet has significant effect in increasing complete combustion of the fuels.

Table 4.2 Engine brake power

Engine Speed (RPM)	**Brake Power (kW)**		
	B0	**B20**	**B20 + Magnet**
1100	0.38	0.37	0.39
1700	0.9	0.85	0.86
2200	1.2	1.12	1.19
2800	1.52	1.44	1.48
3200	1.9	1.74	1.8
3600	2.16	2.04	2.12
3800	2.14	2.06	2.1

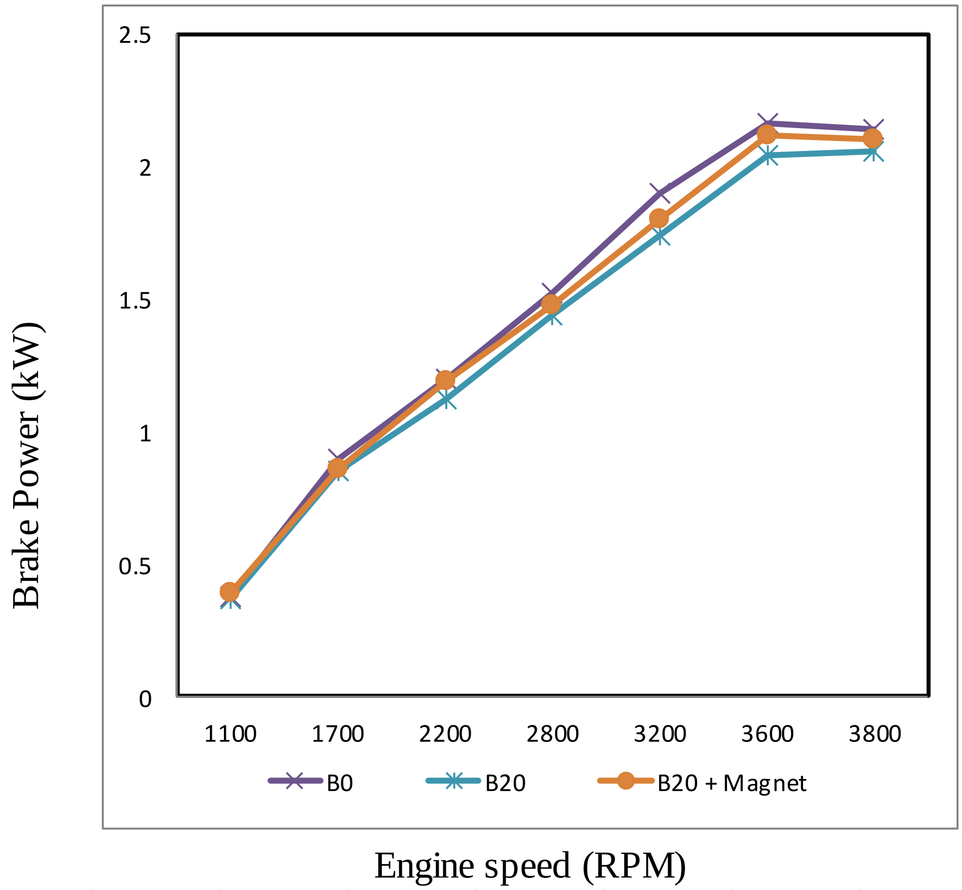

Figure 4.1 Engine Brake power vs engine speed

4.2.2 Engine Brake torque

Table 4.3 Engine Brake Torque

Engine Speed (RPM)	**Brake torque (N.m)**		
	B0	**B20**	**B20 + Magnet**
1100	2.5	2.4	2.45
1700	3.3	3.1	3.2
2200	3.8	3.68	3.78
2800	4.46	4.35	4.45
3200	4.4	4.4	4.45
3600	4.1	3.92	4

The output torque is affected by fuel properties like heating value, viscosity and lubricity. The lower heating values and higher viscosity of COME leads it to have lower output torque than mineral diesel. But by adding the magnet in the fuel line, the output torque shows increment when compared to B20. As recorded from TBMC-3 engine test bench and given in table 4.3, the results of output torques by varying speed was given in Figure 4.2. From the graph it was seen that brake torque increased as engine speed increased until its maximum point and then decreased. The maximum torque was found at the engine speed of 2800rpm, which were 4.46, 4.35 and 4.45 for B0, B20 and B20 + magnet respectively. The reduction of brake torque by 4.7% for B20 was due to the lower calorific values as well as higher viscosity of the COME. It was observed that magnetized B20 fuels has 2.3% higher output torque than that of B20. This result is found due to the fact that the magnet increases the atomization of the fuel which allows to the complete combustion.

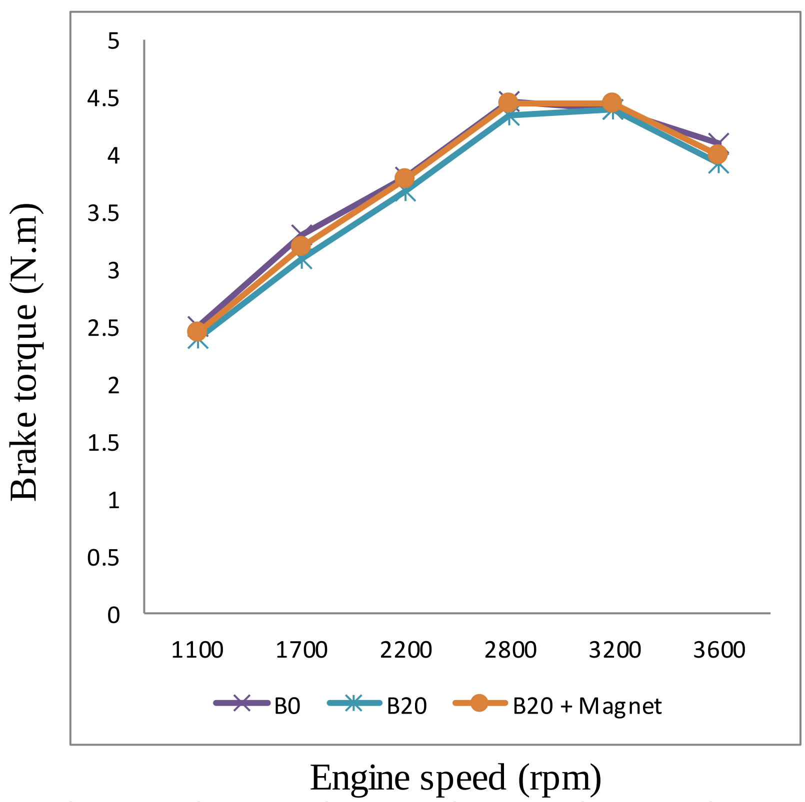

Figure 4.2 Output Torque vs Engine speed

4.2.3 Brake specific fuel consumption

In engine tests, the fuel consumption is measured as a flow rate-mass flow per unit time $\dot{m}_f$. A more useful parameter is the specific fuel consumption (SFC) the fuel flow rate per unit power output. It measures how efficiently an engine is using the fuel supplied to produce work and the brake fuel specific consumption which is measured at brake power was calculated using equation (3) and (4) by having the values of V_f from TBMC-3 engine test bench. The calculated values were given in table 4.4.

The variation of brake specific fuel consumption of B20, B20 + Magnet and diesel with regard to engine speed was given in Figure 4.3. From the test it has been observed that BSFC has increased upon feeding the engine with B20. Increased fuel consumption in B20 in all speed was more than the both B0 and B20 with magnet. The value of BSFC at 1100rpm speed for B20 was increased by 3.25% with respect to diesel, while for B20 with magnet was reduced by 1.8% with respect to B20 without magnet. The reduction of fuel consumption after adding the magnet in fuel line is due to the fuel are actively interlocks with oxygen producing a more complete burn in the combustion chamber. Figure 4.3 shows the comparison of bsfc for all conducted tests.

Table 4.4 Brake specific fuel consumption

Engine Speed (RPM)	BSFC (Kg/KW.h)		
	B0	**B20**	**B20 + Magnet**
1100	366.12	378	371.23
1700	288.27	298.2	281.26
2200	213.27	223.83	216.22
2800	168.76	179.49	169.87
3200	132.24	146.35	144.13
3800	118.91	126.84	121.96

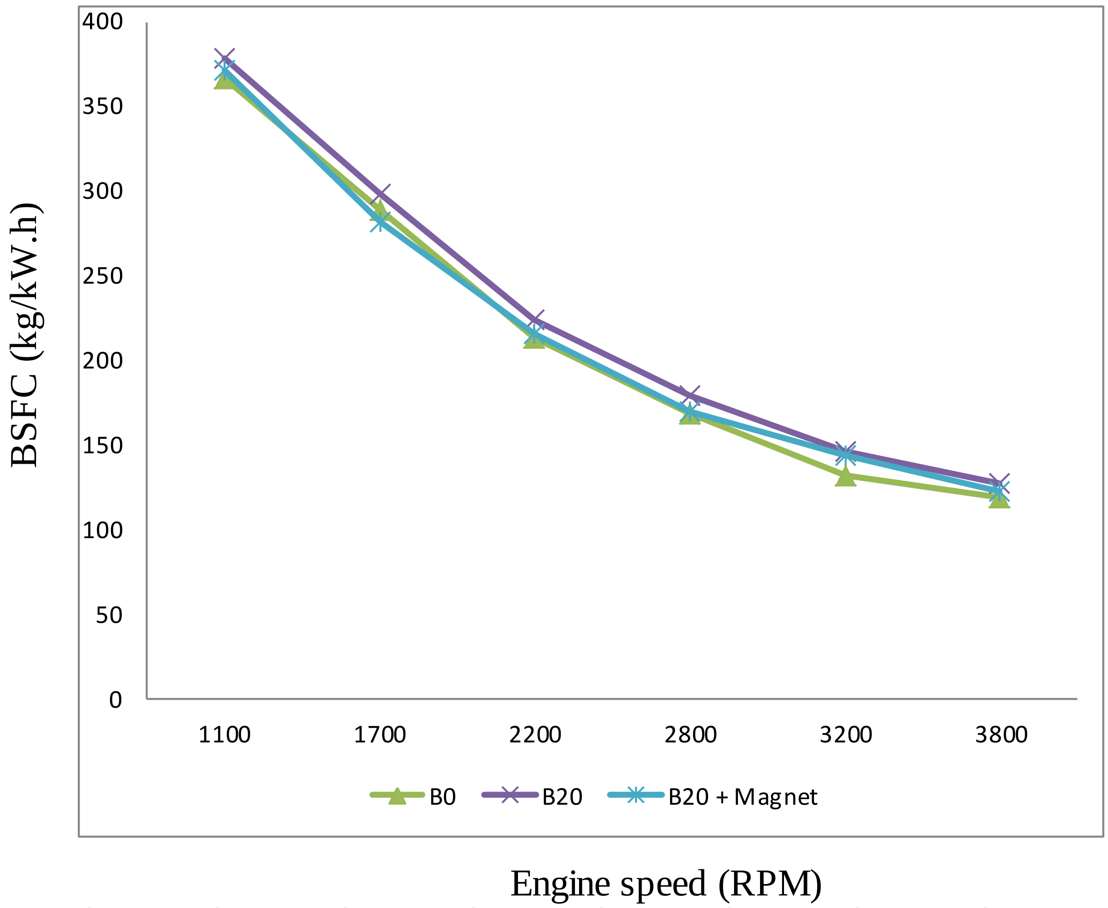

Figure 4.3 Brake specific fuel consumption

4.3 Emission Characteristics

In addition to engine performance parameters, different emission like CO_2, CO, HC, and O_2 from the engine has been investigated during the present study. The results, found from the experiment has been discussed in detail as follows.

4.3.1 CO_2 Emission

The emission of CO_2 relatively high for B20 and B20 + Magnet. Increased CO_2 in the exhaust is due to the excess oxygen present in the COME which reacts with CO to form CO_2. From Figure 4.4, it was observed that as the engine speed increases the CO_2 emission is increases and this is because of the oxidation and conversion of CO to CO_2 at higher engine speed and the result was also reported by other author (Swaroopa et al, 2017). For magnetized B20 fuel the CO_2 emission is found to be higher than that of diesel while it is reduced when compared to B20 without magnet. The reason for this that, the magnetized B20 fuel ionization was increased which leads it to have more complete combustion than that of B20 without magnet.

Table 4.5 Carbon dioxide emission

Engine Speed (RPM)	**Carbon dioxide emission (%)**		
	B0	**B20**	**B20 + Magnet**
1100	2.19	2.35	2.21
1700	2.28	2.4	2.31
2200	2.35	2.44	2.39
2800	2.51	2.61	2.51
3200	2.58	2.78	2.61
3600	2.68	2.81	2.72
3800	2.71	2.92	2.79

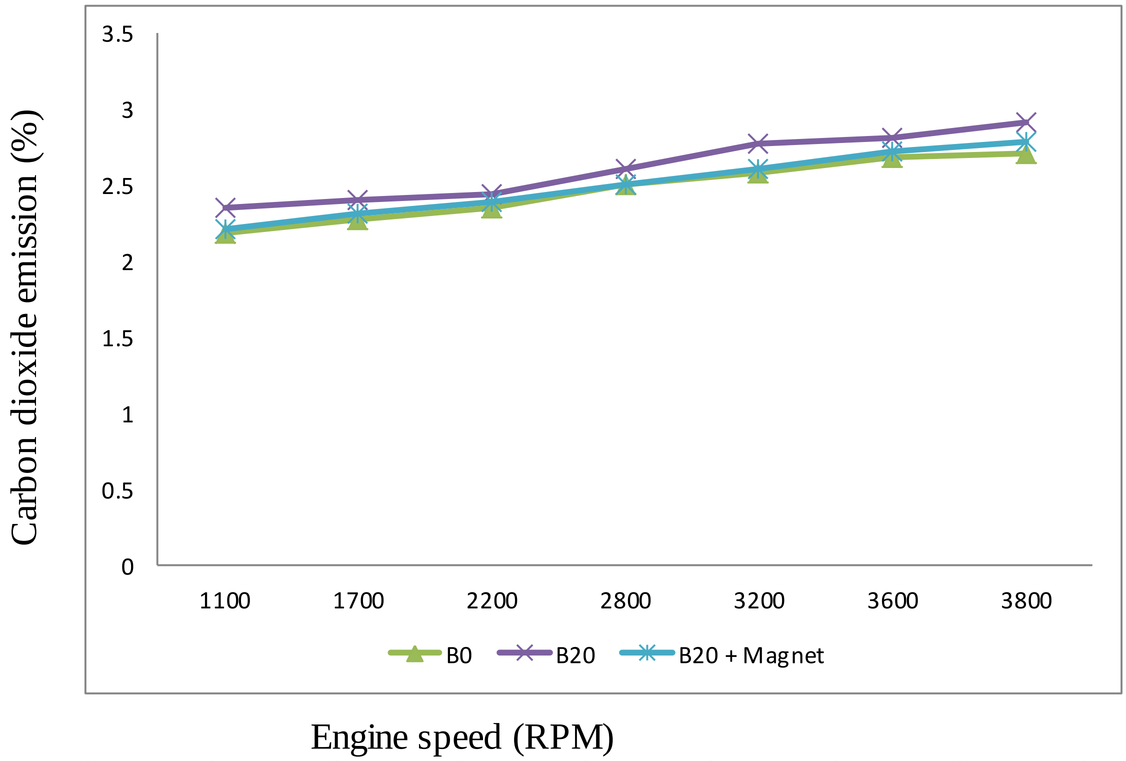

Figure 4.4 Carbon dioxide emission vs Engine speed

The average increase in CO_2 emission for B20 was 5.9%, while for B20 with magnet was shown a reduction of 4.2% than that of B20 magnet. Thus fuel magnetization has a significant effect in reducing CO_2 emission. Table 4.5 shows the recorded data from TBMC-3 engine test bench

4.3.2 CO Emission

Figure 4.5, shows the CO emission for all tests. The oxygen content the castor oil biodiesel in their molecules leads the B20 and B20 with magnet to have lower CO than convensional diesel fuel. At higher speed the exhaust gas temperature increases and this temperature helps in the oxidation of CO and converted to CO_2. These results have also been expressed by other authors and the cause of the same is the content of oxygen in the COME biodiesel blend with diesel (Parvaneh et al, 2017). The mean reduction in CO for B20 with magnet and without magnet was 7.17% and 13.52% respectively. Thus, both castor oil biodiesel and permanent magnet has significant effect in reducing CO emission. Data's recorded from TBMC-3 engine test bench was given in table 4.6.

Table 4.6 CO emission

Engine Speed (RPM)	**CO emission (%)**		
	B0	**B20**	**B20 + Magnet**
1100	0.071	0.063	0.06
1700	0.06	0.055	0.053
2200	0.063	0.059	0.056
2800	0.066	0.061	0.056
3200	0.072	0.067	0.061
3600	0.076	0.072	0.066
3800	0.08	0.076	0.07

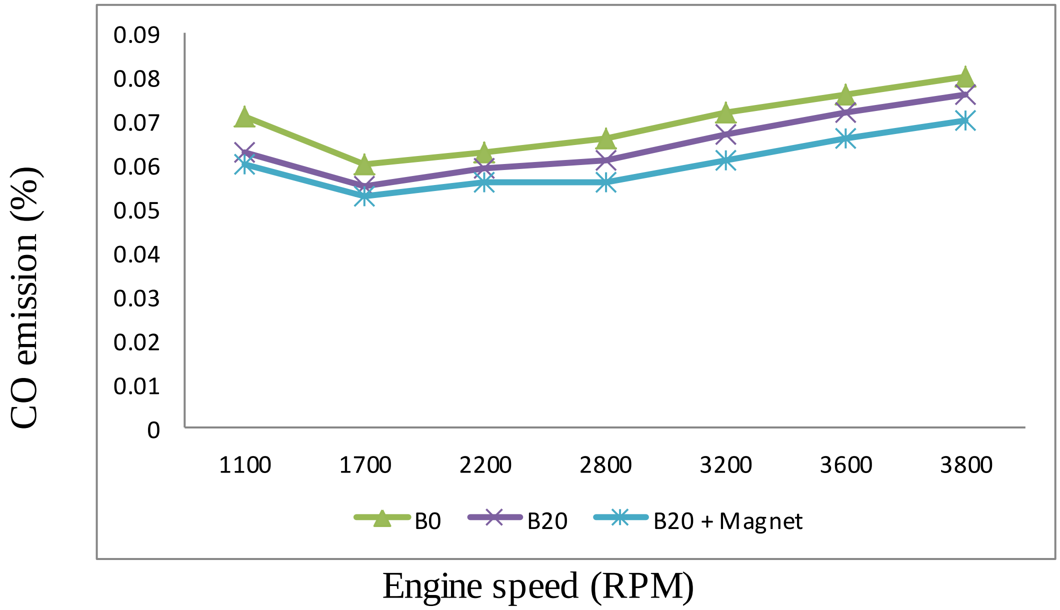

Figure 4.5 CO emission vs engine speed

4.3.3 HC Emission

The variation of HC emission at different speeds for B0, B20 and B20 with magnet was recorded in table 4.7 and shown in Figure 4.6.

Table 4.7 HC emission (PPM)

Engine Speed(RPM)	**HC emission (PPM)**		
	B0	**B20**	**B20 + Magnet**
1100	42	35	32
1700	38	32	30
2200	34	31	29
2800	34	32	30
3200	35	32	31
3600	37	34	32
3800	38	36	34

Substantially the reduction in HC emission has been found for B20 and B20 + magnet. At the speed of 1100rpm, the values of HC are reduced by 16% and 23% for B20 and B20 with magnet respectively. These reductions indicate better combustion of fuels, which is due to the oxygen level of the biodiesel. These results have also been expressed by other authors (Prakash et al, 2018).

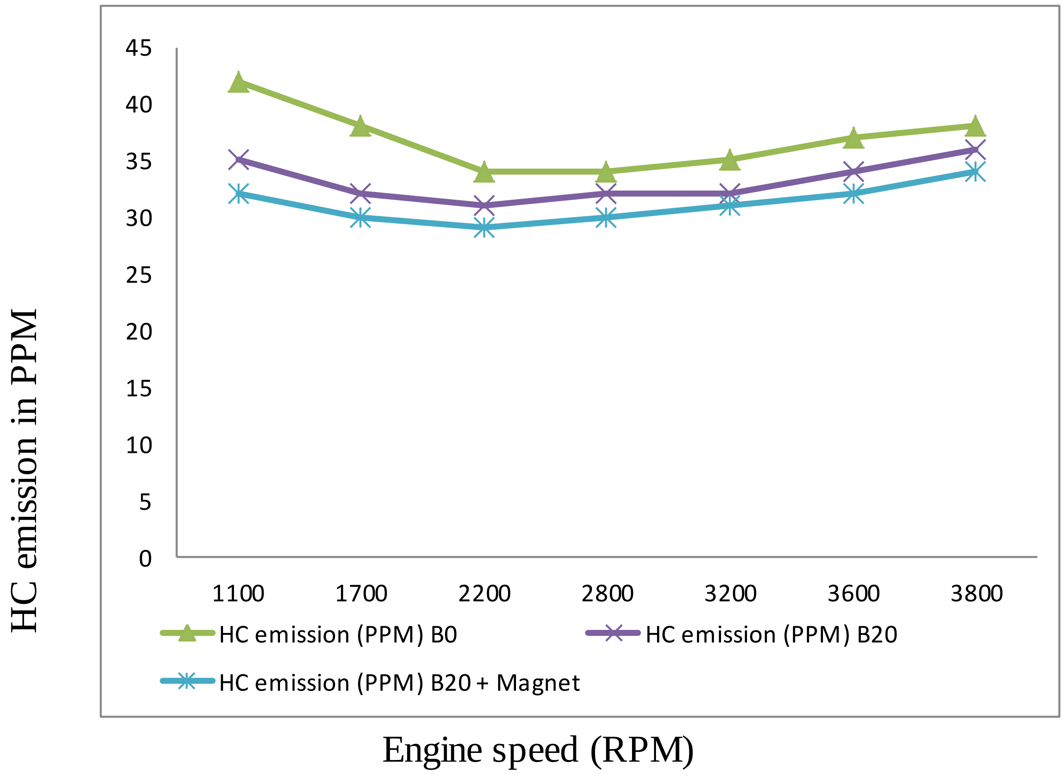

Figure 4.6 HC emission vs engine speed

4.3.4 Oxygen Emission

Figure 4.7, which was drawn from data taken from TBMC-3 engine test bench and given in table 4.8, Shows the emission of oxygen for all tests. From the results COME blends with and without magnet shows better oxygen emissions. The oxygen emission at the speed of 1100rpm was found to be increased by 10% and 14% for B20 without magnet and B20 with magnet respectively. The emission analyses of the CI engine running with biodiesel blended fuel has significantly higher in O_2 emission under working engine operation conditions. This emission increment is most likely a result of the oxygen content in biodiesel and the low carbon hydrogen ratio (Vivek et al, 2018).

Table 4.8 Oxygen emission

Engine Speed (RPM)	Oxygen emission (%)		
	B0	**B20**	**B20 + Magnet**
1100	15.6	17.22	17.82
1700	15.2	16.36	17.2
2200	14.32	16.1	16.7
2800	14.24	15.25	15.65
3200	13.52	14.23	15.14
3600	12.12	13.68	14.62
3800	11.34	12.8	13.42

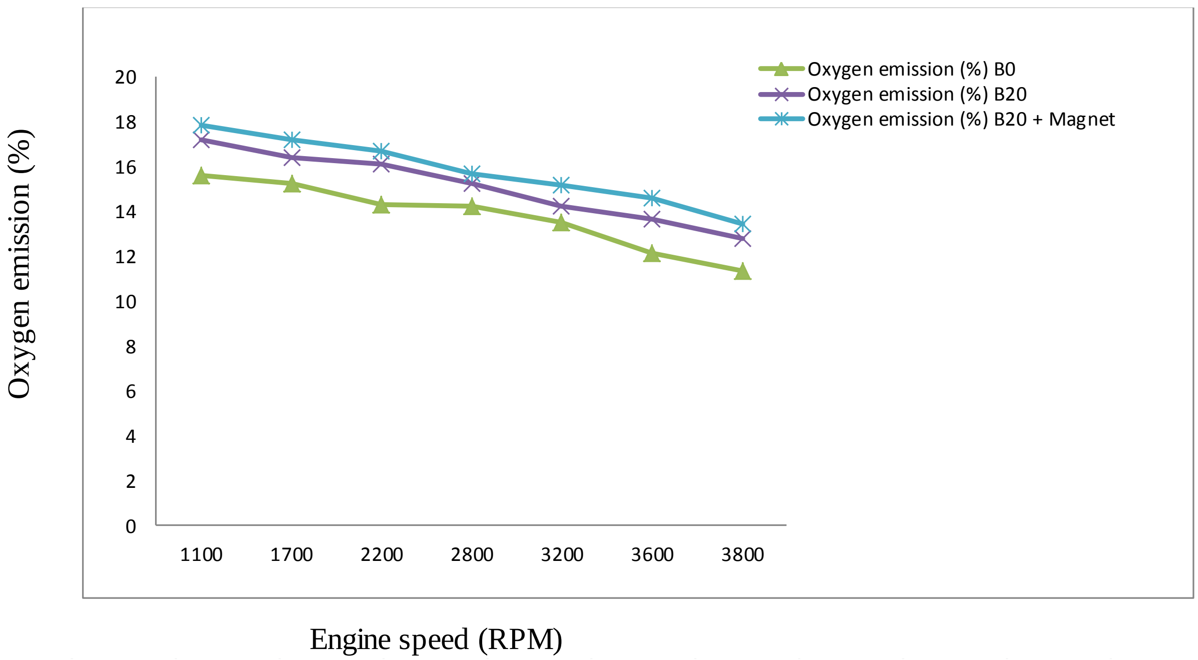

Figure 4.7 Oxygen emission

CHAPTER FIVE

CONCLUSION AND RECOMMANDATION

5.1 Summary

Engine performance parameters and emission characteristics are affected by the complete combustion of the fuel. the complete combustion of the fuel in the combustion chamber can be reached when all fuels are ionized. Ionization is affected by the fuel properties like viscosity and density. Castor oil biodiesel has high viscosity and density, and this can be cause to the difficult of its complete combustion.To overcome this problem the biodiesel was blended with the diesel fuel in the ratio of 20% biodiesel and 80% diesel, in which its viscosity and density was reduced. In addition to this the magnetic force is applied in the fuel line during the experimental tests on the diesel engine to increase the fuel ionization. The engine performance parameters like brake power, brake torque and BSFC and emission charecteristics like CO_2, CO, HO and O_2 are tested and the results are compared with the convensional diesel fuel. Magnetizing fuel was found to be a significant effect on the engine performance parameters and emission characteristics.

5.2 Conclusion

In the present research, experimental tests were conducted on, single cylinder, four stroke diesel engine, to evaluate its performance and emission characteristics, by feeding the fuel of B0, B20 without the magnet and B20 with magnet. The castor oil was produced from castor seeds by mechanical pressing. Then biodiesel was produced from nonedible castor oil by transesterification reaction and blended with the mineral diesel fuel with the proportion of 20% biodiesel and 80% diesel. The properties like viscosity and density of this blended fuel was tested and found to be fulfilled the ASTM D6751 standard.

The prepared blend was tested in the engine and the performance and emission of the engine was investigated. From the experiments the value of brake power was found to cut down by 5.8% for B20 with respect to diesel fuel (B0). Only by using the magnetic force in the fuel line the brake power was upgraded by 3.9% for B20. In both B20 with and without magnet the brake power of the engine shows reduction. Arrangement of magnet in the fuel line has an effect on performance of B20 blended fuel. From the similar tests conducted with three types of fuels, it is observed that the brake torque of B20 is about 4.7% less than B0 and the brake torque of B20 with magnet in fuel line is 2.3% higher than the brake torque of B20 without usage of magnets. Another engine parameter measured was BSFC which was increased by 3.25% and 1.8% for B20 without the magnet and with magnet respectively when compared to B0.

The exhaust emission was also assessed. CO_2 for B20 was greater than that of B0 by 5.9%, while it was reduced down by 4.2% for B20 with magnet when compared to B20 without magnet. CO emission was reduced by 7.17% and 13.5% for B20 without the magnet and B20 with magnet respectively when compared to B0. Similarly, HC emission for B20 without and B20 with magnet was reduced by 16% and 23% respectively with respect to B0. O_2 emission shows an increment for B20 with and without magnet by 10% and 14% respectively.

For all tests it was observed that using COME blend with mineral diesel improves the emission gases like CO, HC and O_2. Using magnet in the fuel line improves all engine parameters when compared to biodiesel without magnet. With regard to mineral diesel magnetized biodiesel shows a substantial reduction in CO and HC, while the O_2 emission was increased and the minor reduction in brake power and brake torque was observed.

5.3 Recommendations

It was clear that the petroleum based fuel is depleting and their price is also increasing year to year. This can be highly affecting the economic and environmental problem. To overcome these problems the following recommendation was made based on the result of the present work: -

- The biodiesel produced from nonedible vegetable oils like castor can recommend to use in diesel engines with a blend of B20
- To improve the combustion of the engine, permanent magnet, which are simply installed in the fuel line, was recommended to be used with COME biodiesel blend with mineral diesel (B20).

5.4 Future Work

The present study concentrates primarily on the issue of fuel magnetization for COME of B20. Based the results found in this study, the following ideas need further investigation.

- The properties of fuel such as pour point, flash point, calorific values and cloud point, which receives a substantial effect on engine parameters, can be tried out in details.
- The issue of magnet can be investigated with increasing the proportion of biodiesel

- The effect of magnetization can be investigated using different source of biodiesel like waste cooking oil, jatropha etc.
- Investigation of emissions like NO_x can be performed

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APPENDICES

Appendix A

Basic Equation

Acid number $= 39.997 \times V \times N$Weight of the sample in gm ....(3.1)..................... 30

$Pb = Tb \times 2\pi N/60$ ....(3.2) 41

Where, P_b is Brake power in kW

T_b is brake torque in N.m

N is Engine speed in RPM

$Tb = 60Pb2\pi N$..(3.3)....................................... 41

Where, P_b is Brake power in kW

T_b is brake torque in N.m

N is Engine speed in RPM

$mf = Vf \times \rho f$ .... (3.4)........................... 42

Where, V_f is the volume flow rate of the fuel in ml/min

ρ_f is density of the fuel in g/ml

$BSFC = mf \times 3600Pb$ .... (3.5).................. 42

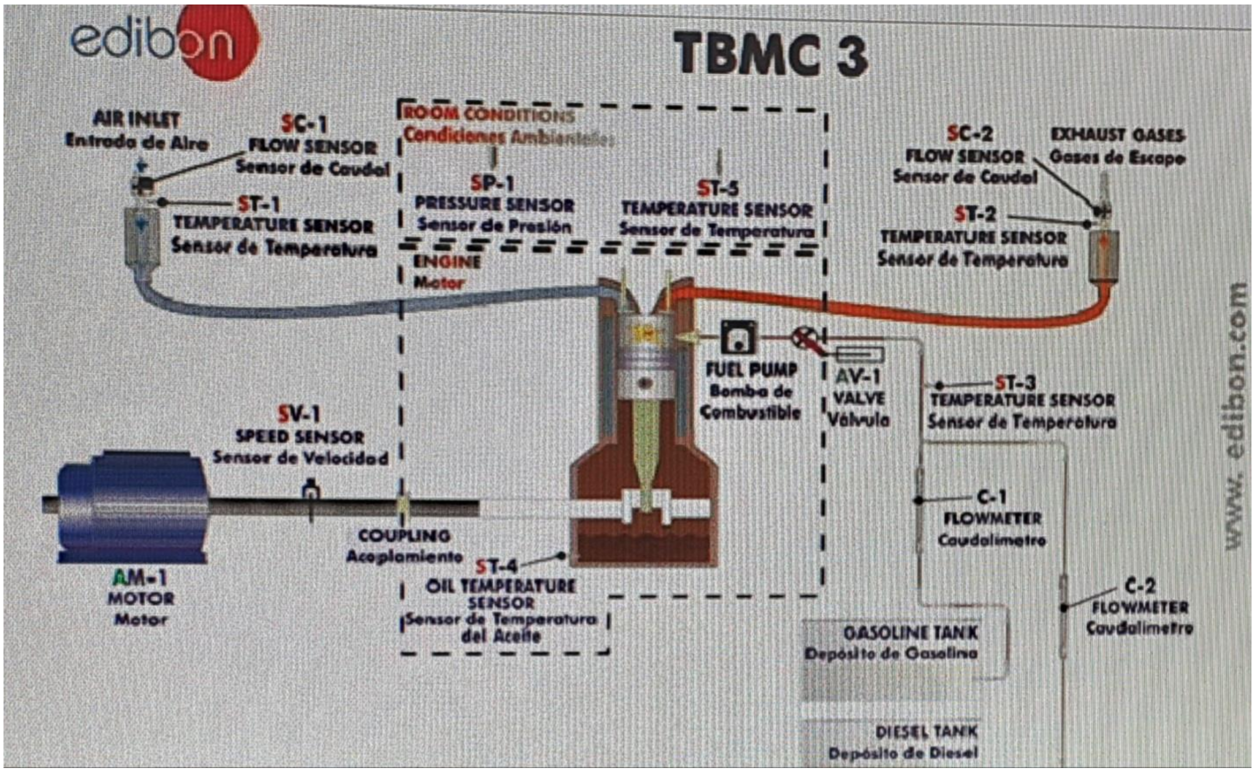
Where, BSFC is brake specific fuel consumption in kg/kW.h

m_f is mass of fuel consumed in kg/s

P_b is brake power in kW

Appendix B

Elements of TBM3-03 computer controlled test bench for single-cylinder diesel engine and its process diagram



Appendix C

Letter of recommendation, that explain experimental performed at their lab, from Addis Ababa Science and Technology.

በአዲስ አበባ ሣይንስና ቴክኖሎጂ ዩኒቨርሲቲ
የኤሌክትሪካል እና ሜካኒካል ምህንድስና ኮሌጅ
መካኒካል ምህንድስና ትምህርት ክፍል

Addis Ababa Science and Technology University
College of Electrical and Mechanical Engineering
Dep't of Mechanical Eng.

ቁጥር አ.አ.ሳ.ቴ.ዩ /ዐዷክ/162/20
Ref. No.
ቀን 15/10/2012
Date

ለአዳማ ሳይንስና ቴክኖሎጂ ዩኒቨርሲቲ

<u>አዳማ</u>

<u>ጉዳዩ፡ የላብራቶሪ አገልግሎት ያገኙ መሆኑን ስለማሳወቅ</u>

ተማሪ **ሲሳይ ሰዩም** ለጥናት እና ምርምር የሚሆን የናፍጣ እና ባዮዲዝል ቅልቅል ናሙና የቤተሙከራ አገልግሎት እንዲያገኙ ወደ አዲስ አበባ ሳይንስና ቴክኖሎጂ ዩኒቨርሲቲ **በቀን 08/ሰኔ/2012፣** ቁጥር፡ **7/2-1-/780/10529/12** በተጻፈ በደብዳቤ ትብብር እንዲደረግላቸው በጠየቃችሁን መሰረት ተማሪው በመካኒካል ምህንድስና ትምህርት ክፍል ስር በሚገኝ ላብራቶሪ Engine dynamometer performance test እና exhaust gas analysis test አገልግሎት ያገኙ መሆኑን እናሳውቃለን።

ከሠላምታ ጋር

[illegible] ገብረሚካኤል ሀብቴ
የሜካኒካል ምህንድስና
ትምህርት ክፍል ሃላፊ

የኤሌክትሪካል እና ሜካኒካል ምህንድስና ኮሌጅ
College of Electrical & Mechanical Engineering

ግልባጭ

- ለአቶ ሲሳይ ስዩም
  <u>አዳማ</u>

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