Performance Investigation on Diesel Engine Fueled with Cotton seed oil Biodiesel Blends with Metal oxide nanoparticles as Additive

Negasa Tesfaye Tefera

A Thesis Submitted to

The Department of Mechanical Systems and Vehicle Engineering

School of Mechanical, Chemical and Materials Engineering

A Thesis Submitted in Partial Fulfillment of the Requirement for the Degree of Master's in Automotive Engineering

Office of Graduate Studies

Adama Science and Technology University

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Oct, 2020 GC

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APPROVAL OF BOARD OF EXAMINERS

We, the undersigned, members of the Board of Examiners of the final open defense by Negasa Tesfaye have read and evaluated his thesis entitled "Performance Investigation on Diesel Engine Fueled with Cotton seed oil Biodiesel Blend with metal oxide nanoparticles as Additive" 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's in Automotive Engineering

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DECLARATION

I hereby declare that this MSc Thesis is my original work and has not been presented for a degree in any other university, and all sources of material used for this thesis have been duly acknowledged.

Name: ______________________________ Signature: _________ Date____________

This MSc Thesis has been submitted for examination with my approval as thesis advisor.

Name: ______________________________ Signature: _________ Date____________

This MSc Thesis has been submitted for examination with my approval as thesis co-advisor.

Name: ______________________________ Signature: _________ Date____________

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LIST OF ACRONYMS AND ABBREVIATIONS

Al_2O_3	Aluminum oxide
ASTM	America society of testing and materials
B0	Pure diesel
B20	20% cotton seed biodiesel and 80% diesel
Bsfc	Brake specific fuel consumption
BTE	Brake thermal efficiency
CDRI	Commo rail direct injection
CI	Compression ignition
CNTS	Carbon nanotubes
CO	Carbon monoxide
CO_2	Carbon dioxide
CeO_2	Cerium oxide
CSO	cotton seed oil
CP	Cloud point
CuO	Copper oxide
FFA	Free fatty acid
Gm	Gram
HC	Hydrocarbon
HHV	Higher heating value
KOH	Potassium hydroxide
Ni	Nickel

$NiZnFe_2O_4$	Nickel Zinc Iron oxide
NPs	Nanoparticles
NOx	Nitrogen oxides
O_2	Oxygen
PP	Pour point
ZnO	Zinc oxide
Ppm	Parts per million
CFPP	Cold filter plugging point
CI	Compression ignition
INP	Iron nanoparticles
Al	Aluminum

ABSTRACT

Fossil fuel is essential for rapidly growing of industrialization, agricultural sector and transportations. These fuels are inadequate and reduced day by day because of usage of fuel increased very rapidly. Additionally, harmful gases released from the used fossil fuel is high and causing problem to environments. These problems inspire to look for advance alternative fuels and renewable energy. The most widely used feedstocks for biodiesel production are vegetable oils. Cotton seed oil is one of the best feedstocks for biodiesel production because it is non-edible and cotton seeds bear good oil content. Biodiesel has several problems like higher viscosity, cold flow issues, low heating value, shorter storage life, higher emission of NOx etc. To reduce this challenge addition of metal oxide nanoparticles as additives was attracting the attention of researchers for improving the performance of the fuels. Thus, this thesis work was aimed the performance investigation on diesel engine fueled with cotton seed oil biodiesel with three elemental (Nickel Zinc Iron oxide) metal oxide nanoparticles as additive. This work done through the various steps like production of biodiesel by transesterification process, blending diesel-biodiesel with Nickel Zinc Iron oxide nanoparticles in different proportions using ultrasonicator and characterization of fuels. The blends prepared were B20 (80% diesel and 20% biodiesel in volume), B20+25ppm (80% diesel ,20% biodiesel and 0.025 gm $NiZnFe_2O_4$), B20+50ppm (80% diesel ,20% biodiesel and 0.05 gm $NiZnFe_2O_4$) and B20+100ppm (80% diesel ,20% biodiesel and 0.1 gm $NiZnFe_2O_4$). The engine performance and exhaust emission tests were conducted on single cylinder four stroke CT 110 Test Stand Diesel Engine. From performance test results, cotton seed biodiesel blended with $NiZnFe_2O_4$ shows B20+100ppm had higher brake power and brake torque than other diesel-biodiesel blends and neat diesel fuel. Brake power and brake torque produced by B20+100ppm were 4.98 kW and 14.38 Nm respectively, Brake specific fuel consumption of cotton seed biodiesel blended with Nickel Zinc Iron oxide was decreased compared to the pure diesel. Addition of $NiZnFe_2O_4$ also improved exhaust emission compared to pure diesel. Generally, from experimental investigations concluded that cotton seed biodiesel blended with Nickel Zinc Iron oxide nanoparticles can be used safely without any modification in engine.

Keywords: *Cotton seed oil, biodiesel, Transesterification, Ultrasonicator, nanoparticles, Diesel engine, Performance and Exhaust emission*

CHAPTER ONE

INTRODUCTION

1.1 Background

Fossil fuel is essential for rapidly growing of industrialization, agricultural sector and transportations. These fuels are inadequate and reduced day by day because of use of fuel increased very rapidly. Additionally, harmful gases released from the used fossils fuel is high and causes may problems to environments. These problems inspire to advance alternative fuels and renewable energy (Sadeghi Azizzadeh,2015).

Biodiesel is one alternate fuel which potential to substitute a current fossil fuels because of its low GHG emission, nontoxic, good lubricating quality and its product is normally biodegradable. In addition, the biodiesel combustion properties in the diesel engine is good because of their number of cetane high, Sulphur and aromatic content is low and also used as a fuel in aircraft. Biodiesel fuel has the ability to decrease the level of pollutants and probable the substances causing diseases. It has a potential to use in any diesel engine without the need to redesign any components of conventional diesel engine and also an ecologically sociable fuel. It has better quality emission of exhaust gas and it does not increase the level of CO_2 in the atmosphere and consequently to the greenhouse effect. The emission from biodiesel combustion contained lower amounts of CO_2, CO, HC and smoke but supposing of increasing emission level of Nitrogen oxides (Sadeghi Azizzadeh,2015).

Today, biodiesel is getting international consideration because of its fuel properties and compatibility but it is produced from edible oil feedstock, such as soybean oil, palm oil, rice bran oil and rapeseed oil. The growing usage of edible oil feedstock has aggravated the food scarcity problem, it leads to conflict between the food supply and demand for biodiesel in the world market. Nevertheless, to overcome the problem, maintainable expansion of biodiesel production is required to meet the future challenges. Now biodiesel production from non-edible oils feed stock is discovered to reduce food fuel debate. Non-edible oils like cotton seed oil, castor oil, Jatropha oil, Pongamia oil, mahua oil, and linseed oil were discovered for production of biodiesel (Sadeghi A.,2015). In several countries varied oils are used as raw materials for biodiesel production as a result of its availableness. Soybeans are commonly used in the USA. In Malaysia and Indonesia, the palm oil was used as major biodiesel supply. In Europe, rapeseed oil was the most common based oil used in biodiesel production. In Asian and south east Asia, the jatropha tree is employed as a major fuel supply (Abbas A. et al., 2015).

The properties of biodiesel typically have higher density, viscosity, cloud point, cetane number, lower volatility and heating value compared with diesel fuel. These properties effects on engine performance and emissions. However, using optimized blend of nanoparticles with diesel-biodiesel will help to reduce these high properties or its blends could also use in the present diesel engine with no modification on the engine parts. Using optimized blend of nanoparticles and diesel rather than conventional diesel fuel considerably reduces of particulate matter (PM), Sulphur oxides (SO_X) and burned hydrocarbons (HC). with the utilization of fuel additives within the blend of nanoparticles and diesel improves performance and fuel properties that enhance the combustion characteristics (A. Selvaganapthy et al.,2013).

The researchers are targeted on single biodiesel with nano fuels blends like soybeans, rapeseed oil, Pongamia pinnata oil, cottonseed oil, neem oil, castor oil, Mahua oil, jatropha oil, lined oil, rice bran oil etc. and its blended with diesel (Demibras A,2009). From the previous literature's studies, many researchers worked on the investigation of performance and emission of biodiesel blended with diesel fuel with/without nanoparticles addition in diesel engine. This thesis study was designed to analyze the result of the performance and emissions of cotton seed oil biodiesel blended with diesel fuel with addition of Nickel Zinc Iron oxide nanoparticle on diesel engine. The Nickel Zinc Iron oxide nanoparticles was added with various proportions.

1.2 Nanoparticles as a fuel additive

There is a more possibility for enhancement in biodiesel fuel properties by addition of metal oxide nanoparticles as fuel additives for improvement in the rate of heat transfer, stabilization and enhancement of the thermophysical properties of fuel mixtures, increase the performance parameters of engine and decrease in the exhaust emissions. A fuel additive mostly increases the combustion efficiency and reduces the pollution. These additives increase cetane number of the fuel, which in turn advances the ignition characteristics as well as reduces the oxidation temperature of fuel (K. Mishra et al.,2010).

Addition of some metal and metal oxide in the form of nano-powder to the base fuel may enhance the properties of the fuels. This is due to the interesting properties of nanoparticles like higher specific surface area, thermal conductivity, catalytic activity and chemical properties as compared to their bulk form. Moreover, nano-particles as additives in diesel as well as biodiesel as new hybrid fuel blends. The properties of nano-particles such as size, thermal conductivity and chemical properties affect the performance and emission characteristics of engine. Reduced size of the nano-particles increased specific surface, surface to volume ratio, and surface area improving catalytic reactivity and magnetic properties as compared to their bulk form. Hence metal and metal oxide nano-particles addition to biofuel will improve the performance as well as reduce the harmful gases from engine exhaust. Addition of nano-particles to biodiesel may also be effective as they enhanced surface area to volume ratio. Flash point of biodiesel, which is an indication of the volatility, was found to increase with the inclusion of such additives making them safer fuels. The viscosity of biodiesel was found to increase with the addition of nano-particles to biodiesel. The viscosity and the volatility were found to hold direct relations with the dosing level of the nano-particles (A. Selvaganapthy et al.,2013).

Therefore, nano-particles can function as both catalyst and an energy carrier when used in base fuels in diesel engines. In addition, small scale of nano-particles, also facilitate stability of fuel suspensions when used with base fuels (Aydin Huseyin et al.,2013)

Recent advances in nanotechnology enables production, control and characterization of nanoscale energetic materials. Nanoparticles are more effective than bulk materials because of its higher surface area. Generally, adding of metal oxide nanoparticles to the conventional and biodiesel fuel increase the fuel properties. This is due to the fascinating properties of nanoparticles like higher thermal conductivity, specific surface area and chemical properties as compared to their bulk form (K. Mishra et al.,2010).

1.3 Statement of the problem

As the increasing the demand of fossil fuels day by day and limited amount of petroleum resource have caused interest in the development of alternative fuel for internal combustion engines. On other hand environmental pollution got attention due to the combustion of fossil fuels from automobiles and industries increases exhaust emissions. Biodiesel is the most potential alternative fuel source intended to replace fossil fuels, and the longevity and cleanliness of diesel engines. Biodiesel is derived from biological sources, such as vegetable oils, plant oil and animal fats. Biodiesel offer the best promising substitute to diesel fuel since they have similar properties with conventional fuel and they are renewable. However, as different researchers had been investigated on biodiesel, biodiesel has low engine performance and high viscosity that effects on engine during injection in combustion. Additionally, biodiesel increases the emission of nitrogen oxides. To reduce this challenge addition of nanoparticles to diesel-biodiesel blends as additives are effective solution to improve engine performance, exhaust emissions and fuel properties of the biodiesel in all aspects. The intention of this thesis work is to solve the above-mentioned problems.

1.4 Objectives

1.4.1 General Objective

The general objective of this study is to investigate the performance characteristics of diesel engine fueled with cotton seed oil biodiesel blends with metal oxide nanoparticles as additives.

1.4.2 Specific Objectives

- To produce cotton seed oil biodiesel by transesterification method.
- To prepare diesel-biodiesel blends with nanoparticle using ultrasonicator.
- To characterize the properties of test fuels.
- To evaluate the performance and emission of diesel engine operated with metal oxide nanoparticles.
- To analyze and compare the results with commercial baseline diesel fuel.

1.5 Significance of the study

The results of the study were greater benefit to the followings:

- It reduces the country's budget on imported oil and ensuring the availability of alternative fuel.
- It increases the quality of environment by reducing emissions of greenhouse gases.
- Gives substitute fuel for commercial diesel engines.
- It promotes the cotton seed oil biodiesel.

1.6 Beneficiary of the study

Automobile industries, vehicle owners, researchers, farmers, Society and country are benefited from this study.

1.7 Scope of the study

The scope of the study is testing performance and exhaust emission of biodiesel produced from cotton seed oil with addition of three elemental nanoparticles on CI engine. Production of biodiesel from cotton seed oil and blending of diesel-biodiesel with addition of Nickel Zinc Iron oxide nanoparticles were done in this work. Characterization activity was also done in this work. Finally, this work concerns the investigation of the performance and exhaust emission analysis of CI engine fueled with cotton seed biodiesel with Nickel Zinc Iron oxide nanoparticles. The fuel samples studied were B20, B20+25ppm, B20+50ppm and B20+100ppm.Under this experimental investigation the engine performance analyzed were brake power, brake torque and brake specific fuel consumption and exhaust emission analyzed were CO, CO_2, HC and O_2.

1.8 Organization of the study

This thesis work structure was organized with the following chapters.

Chapter One: It covers background of the study, describes about statement of problem and also included objectives, significance, scope and organization of the study.

Chapter Two: It covers definition of biodiesel, biodiesel production process, biodiesel qualities, fuel additives and summary of related works.

Chapter Three: This chapter deals with materials and methods of the work. It covers, biodiesel production by transesterification process, diesel-biodiesel blend with nanoparticles and experimental setup.

Chapter Four: This chapter explain the result of tested fuel samples and discussion on the performance of tested fuel samples

Chapter Five: This chapter describe conclusion and recommendations.

CHAPTER TWO

LITERATURE REVIEW

This chapter reviews the definition, source, production, properties and quality of biodiesel as well as definition and types of fuel additives. furthermore, in this section there are also related studies which are reviewed in detail for current studies. These are thesis, international journals and dissertation works.

2.1 Introduction

Petroleum-based fuels are used in almost all sectors of transportation. As the demand of these fuels increases, the price of the fuel also keeps on increasing which has become a great setback for the nation's economy. It is becoming increasingly important to develop sustainable solutions to our energy needs. As fossil fuels are depleting at a faster rate and global warming more heavily affects our lives, the urgency of finding a solution to these problems is more obvious. Energy is considered a critical reason for economic growth, social development, and human welfare. Since their exploration, the fossil fuels continued as the major conventional energy source. With the trend of modernization and industrialization, the world energy demand is also growing at a faster rate. To cope up the increasing energy demand, the majority of the developing countries import crude oil. This puts extra burden on their home economy (S. Kent et al., 2012)

Globally, the awareness of energy issues and environmental problems associated with burning fossil fuels has encouraged many researchers to investigate the possibility of using alternative sources of energy instead of oil and its derivatives. Among them, biodiesel seems very interesting for several reasons: it is highly biodegradable and has minimal toxicity, it can replace diesel fuel in many different applications such as in boilers and internal combustion engines without major modifications and small decrease in performances is reported, almost zero emissions of sulfates, aromatic compounds and other chemical substances that are destructive to the environment, a small net contribution of carbon dioxide (CO_2) when the whole life-cycle is considered (including cultivation, production of oil and conversion to biodiesel), it appears to cause significant improvement of rural economic potential (S. Kent et al., 2012).

The invention of the vegetable oil fueled engine by Sir Rudolf Diesel dated back in the 1900s. However, full exploration of biodiesel only came into light in the 1980s as a result of renewed interest in renewable energy sources for reducing greenhouse gas (GHG) emissions, and alleviating the depletion of fossil fuel reserves. Biodiesel is defined as mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats and alcohol with or without a catalyst. Compared to diesel fuel, biodiesel produces no sulfur, no net carbon dioxide, less carbon monoxide, particulate matters, smoke and hydrocarbons emission and more oxygen. More free oxygen leads to the complete combustion and reduced emission (Shahid,2013). Biodiesel has been in use in many countries such as United States of America, Malaysia, Indonesia, Brazil, Germany, France, Italy and other European countries. However, the potential for its production and application is much more. Biodiesel has been in use in many countries such as United States of America, Malaysia, Indonesia, Brazil, Germany, France, Italy and other European countries (A.E. Atabani et al.,2012).

2.2 Definition of Biodiesel

Biodiesel is defined by ASTM as "a fuel comprised of mono alkyl esters of long-chain fatty acids derived from vegetable oils or animal fats, designated B100". Congress has adopted a similar definition for "biomass-based diesel," with the additional requirement that the fuel have life-cycle greenhouse gas (GHG) emissions that are at least 50% less than baseline life-cycle GHG. The vegetable- and animal-derived feedstocks used to produce biodiesel are known as triacylglycerides (TAGs), or more simply, triglycerides. Biodiesel is produced by a chemical process known as transesterification, by which the triglycerides are reacted with alcohols, in the presence of a catalyst, to produce fatty acid alkyl esters. A byproduct of transesterification is glycerin, also known as glycerol. Since the most common alcohol used to produce biodiesel is methanol, another name for biodiesel is fatty acid methyl esters (FAME). Unless otherwise indicated, the term "biodiesel" refers to neat material – i.e. 100% FAME, often designated as B100. Lower concentrations, such as B20, are properly referred to as "biodiesel blends," not biodiesel itself (S. Kent et al., 2012).

Production of biodiesel used different source of feedstocks like vegetable oils, algal oils, animal fats, microbial oils and waste oils. Biodiesel produced from raw vegetable oil has its properties almost similar to diesel, so that it can be used as an alternate fuel. The main problem of biodiesel as compared to petro diesel are high cloud and pour point, high density, increased nitrogen oxides emission, high viscosity, less volatility, lesser energy content and poor spray characteristics (Singh D. et al.,2019). Biodiesel can be used directly in engine in pure form or blend with diesel in numerous proportions to provide alternative solution of fuel in diesel engines. Biodiesel is renewable source of energy, sulfur free, oxygenated, sustainable and biodegradable. In compression ignition engine no modification is needed while using biodiesel as fuel (Shahabuddin et al.,2013). Several reasons for biodiesel used as alternative fuel are concentrated on reduction of greenhouse gas (GHG) emissions, decrease effect on global climate, sustainable and renewable energy solution and to get more promising alternate fuel supply to encounter the current energy demand. With the aid of biodiesel emissions of CO, unburned HC, CO_2 and particulate matter can be reduced Fuel economy and emissions from engine is greatly affected by fuel injection system. The parameters of fuel injection systems are fueling, injection duration, injection pressure (IP), and injection timing (IT). The parameters of diesel engine performance like brake torque (BT), brake power (BP), brake specific fuel consumption (BSFC) and brake thermal efficiency (BTE) are also improved (Digambar,2020).

2.3 Feed stocks for biodiesel production

Biodiesel can be found from different feedstocks like vegetable, algae, microbial oil and animal fats. Biodiesel obtained from different feedstocks have various purity and composition (Mahdavi M.et al.,2015). The main steps for the biodiesel production are availability of feedstocks, type of feedstocks, selection of feedstock and classification of feedstocks into edible, on-edible and waste-based origins. selection of feedstock influence various factors, like purity of biodiesel, cost, composition and yield. Selection of feedstocks for biodiesel production is also dependent on regions. Availability and economic aspect of country is mainly considered before selecting feedstock. Canola oil is used as feedstock in Canada and Soybean oil is used as feedstock in Brazil and USA. Coconut and Palm oils are used in Indonesia and Malaysia as biodiesel feedstock and Rapeseed oils used in Italy, Germany, Finland and UK as biodiesel feedstock. Karanja and Jatropha have considered as future feedstocks for biodiesel in India.

Among them, Sunflower oil, Rapeseed oil, Soybean oil and Mustard oil have been used previously as biodiesel feedstock but due to unfavorable result on food plants slowed down their utilization as biodiesel feedstocks. The utilization of edible oils as biodiesel feedstocks have big issue because this directly affect food chain (Digambar,2020).

Choosing the proper feedstock is a vital subject to ensure low production cost of biodiesel. As much as possible the feedstock of biodiesel should satisfy two requirements for production of biodiesel which are low production costs and large-scale production. In general, biodiesel feedstock can be categorized into four generations.

2.3.1. First generation biodiesel

First generation biodiesels are produced from the edible feedstocks. These feedstocks are Coconut oil, Rapeseed oil, Olive oil, Corn oil, Palm oil, Rice oil, Soybean oil, Mustard oil etc. (Mahdavi M.et al.,2015). At beginning of biodiesel era use of edible feedstock for the production of biodiesel is quite popular. Availability of crops and relatively easy conversion procedure are the main benefits of the first-generation feedstocks. the main drawback in use of these feedstocks is limitation in food supply that increase the cost of food products (Singh D et al.,2019). High cost, limited area of cultivation and adaptability to environmental conditions are also the difficulties for the production of biodiesel from edible feedstock. These problems forced users to shift on the further alternate sources for the biodiesel production (Tariq M. et al.,2012).

2.3.2. Second generation biodiesel

Second generation biodiesels are produced from the non-edible feedstocks. These feedstocks are Jatropha oil, Neem oil, cottonseed, Karanja oil, Calophyllum inophyllum oil, argemone Mexicana, Rubber seed oil, Mahua indica oil, linseed, Nagchampa oil, Rubber seed oil etc. Disadvantages of first-generation feedstocks fascinate researchers to work on non-edible feedstocks. The main benefits of second-generation biodiesel are less production cost, eco-friendly, eliminates food inequality and less requirement of land for farming are (Tariq M. et al.,2012). Drawbacks of second-generation fuels is yields of plants, where yield falls for main non-edible plants like Jatropha oil, Jojoba oil and Karanja oil. These feedstocks can cultivate in unimportant lands. That’s why it is forced to farm non-edible crops at farming lands; it directly influences economy of society and the food production. To solve the socioeconomic issues of nonedible oil, the researchers paying attention on new alternate solution, which are economically feasible and simply accessible at greater extent (A.E. Atabani et al.,2012).

2.3.3. Third generation biodiesel

Third generation biodiesel is the biodiesel produced from microalgae and waste oils (A.E. Atabani et al.,2012). The major benefits of third generation biodiesel are higher amount of oil percentage, reduced greenhouse effect, elevated growth rate and productivity, minor struggle towards farming land and smaller influence on food supply. The main problems of third generation biodiesel are required huge amount of investment, difficulties in oil extraction, matter of production at larger scale and requirement of sunlight. The main sources for third generation biodiesel are micro algae, animal fat, fish oil, waste cooking oil etc. (Mannon M. et al.,2010). All these possible resources of third generation biodiesel beat the issues faced by previous generation feedstocks that affect the food chain and economic feasibility. In case of waste fish oil, waste animal tallow oil, waste oils and used cooking oil are also sources for the third-generation biodiesel. It also reduces load of waste handling plant and reduction of water pollution. At current animal fats like goat, beef, poultry rising and pork as a possible and dependable source for biodiesel production (Mata et al.,2010).

2.3.4. Fourth generation biodiesel

Photobiological solar fuels and electro-fuels are considered in fourth generation of biodiesels. Solar biofuels are produced by conversion of solar energy into biodiesel using raw material, this method of conversion is a new field of research. Raw materials are widely available, inexhaustible and cheap. Synthetic biology is an enabling technology for such a transformation (Cameron D. et al.,2014). For sustainable development, new-to-nature solutions must be found out, which make synthetic living firms and stylish microorganisms for efficient and direct change of solar energy to fuel. Similarly, a mixture of photovoltaic or inorganic water-splitting catalysts with metabolically engineered microbial fuel development is a rising methodology for efficient development and liquid fuel storage (Digambar,2020).

2.4 Cotton seed plantation in Ethiopia

The main producer countries of Cotton crop are Europe, China and United States. In 2007, cotton was grown in 90 countries. In 2006/07, the four main producing countries were China, India, USA and Pakistan and accounted for approximately three quarters of world output. If we added Uzbekistan and Brazil, six countries would account for 83% of world cotton production. The leading cotton-growing countries in Africa are Egypt, Tanzania, Chad, Mali, Benin, Burkina Faso etc. Ethiopia's share is total cotton produced in Africa is about 5%. Ethiopia yearly produces around 120,000 tons of cotton (Central statistics Agency). Much of the cotton production in Ethiopia is from small-scale farmers, who cultivate about 39,600 hectares annually. The total area under cotton plantation by the private owned enterprises is 54,000 hectares. The country produces cotton both for the local and export markets. According to the Report on large and Medium Scale Manufacturing and Electricity Survey (2002) of the Central Statistical Authority (CSA). In 2007/08, the country's textile industries used 52,936 tons of locally produced cotton as raw material. In the same year, export of cotton from the Country was 14,360 tons valued at US$ 19 million.

Majority of the cotton cultivation takes place in the Awash Valley, with some cultivation also taking place in Gambela, Humera, and Metema. The cotton farming cycle varies from area to area. Cotton is planted earliest (by mid-April) in the case of Middle Awash, while in Lower Awash planting of cotton takes place in late June. Harvesting of cotton shows less time variation. There are four varieties of cotton that are usually cultivated in Ethiopia. These are:

- Mid-Awash
- Bazen
- Hiwot
- Semen Omo

In terms of production methods, almost all of the government-owned and private sector plantations adopt standard cultivation practices. Bulk of the cultivation is in rain fed areas, with only a small part of total cultivated area under irrigation. Pesticides and fertilizers are typically applied whenever required. On the other hand, smallholder cotton farms are rainfed and cotton cultivation is typically organic. The cotton is hand-picked and transported to ginneries (Ethiopian Investment Agency,2012).

2.5 Cotton seed oil composition

The main species of Cotton plants are Gossypium hirsutum and Gossypium herbaceum, which are used for the production Cotton seed oil. the height of cotton plants can reach up to 1.2 m. This oil has numerous kinds of non-glyceride things, like carbohydrates, gossypol, sterols, resins, phospholipids, and connected pigments (Fontaras G. et al.,2007). Cotton seed oil has density in the range of 917–933 kg/m^3(at 15 °C). heating value and viscosity of Cotton Seed oil are 39.5 MJ/kg and 34.79 mm^2/s (at 40 °C) respectively. Cotton seed have oil in the range of 17–25%. The cotton seed oil has fatty acid, like oleic of 19.2–23.26%, palmitic of 11.67–20.1%, and linoleic acid of 55.2–55.5% (Digambar,2020).

2.6 Methods of biodiesel production

Biodiesel production used oils from of vegetable feedstocks, animal fats, microalgae and waste oils. The yield of biodiesel from oil crops mostly depends on the crop species. The yield of biodiesel produced from oils of third generation feedstocks is less in comparison with oil from first- and second-generation feedstocks (Karmaker A. et al.,2010). The production of biodiesel involves two major steps. The first one is extraction of oil from seeds and the second step is conversion of oil in biodiesel using different major techniques like transesterification, pyrolysis, dilution, micro-emulsification etc. Transesterification process is the most adaptive method for commercial biodiesel production because it was most economic process with high biodiesel yield (Digambar,2020).

2.6.1 Pyrolysis

Pyrolysis is one method which is used for biodiesel production in which thermal decomposition of material occur at high temperature in absence of air or in inert atmosphere. This process affected with variation in chemical composition of material. When oil is used as raw material during heating it will break and features of its liquid portion is like as diesel fuel. The characteristics of biodiesel gained from pyrolysis process have viscosity, flash point and pour point less than diesel and calorific value similar to diesel fuel. biodiesel produced through pyrolysis process have cetane number lesser than diesel. Biodiesel produced by method has adequate quantity of sulfur and water, but it has in adequate amount of ash content and residual carbon (Francis G. et al.,2005). High installation cost is the major problem of this process. Based on operating parameters pyrolysis method is classify into three sub categories-

(a) flash pyrolysis process: is a high heating rate (> 1000 °C/s) thermal cracking process.
(b) conventional pyrolysis process: It takes very less vapour residence time to minimize cracking to provide high liquid yield
(c) fast pyrolysis process: It reduces the yield of bio-oil in comparison to conventional pyrolysis.

2.6.2 Micro-emulsification

Micro-emulsion method can be eliminated the issue of viscosity of vegetable oil. It is the transparent, stable and isotropic mixture of oil, water and surfactant. It is colloidal dispersion that is thermodynamically stable. Cetane improver, alcohol, co-solvent and surfactant are added during preparing micro-emulsion of oils. Production of biodiesel by micro-emulsion with butanol, hexanol and octanol is when the maximum viscosity required for fuel. micro-emulsion process is easy. some issues with micro emulsification are less stability, volatility and high viscosity are (Gude V. et al.,2013).

2.6.3. Dilution

Dilution is the method in which amount of solvent increased in solution by decreasing the amount solute. For dilution of oils ethanol and diesel fuel can be used as solvent. The results from this process are reduction in viscosity and density of oil. If 4% amount of solvent (ethanol to diesel fuel) is added to oil the brake thermal efficiency, brake torque and brake power increases but brake specific fuel consumption decreases. dilution process is easy but there are some problems are related with it like incomplete burning and carbon deposition in engine cylinder (Digambar,2020).

2.6.4. Transesterification

Biodiesel produced from transesterification process have similar properties with petro diesel fuel and due to economic point of view transesterification process is favorable for commercial production. During transesterification process esters and glycerol are formed when triglyceride reacts with alcohol. Figure 2.1 shows the transesterification reaction for biodiesel production.

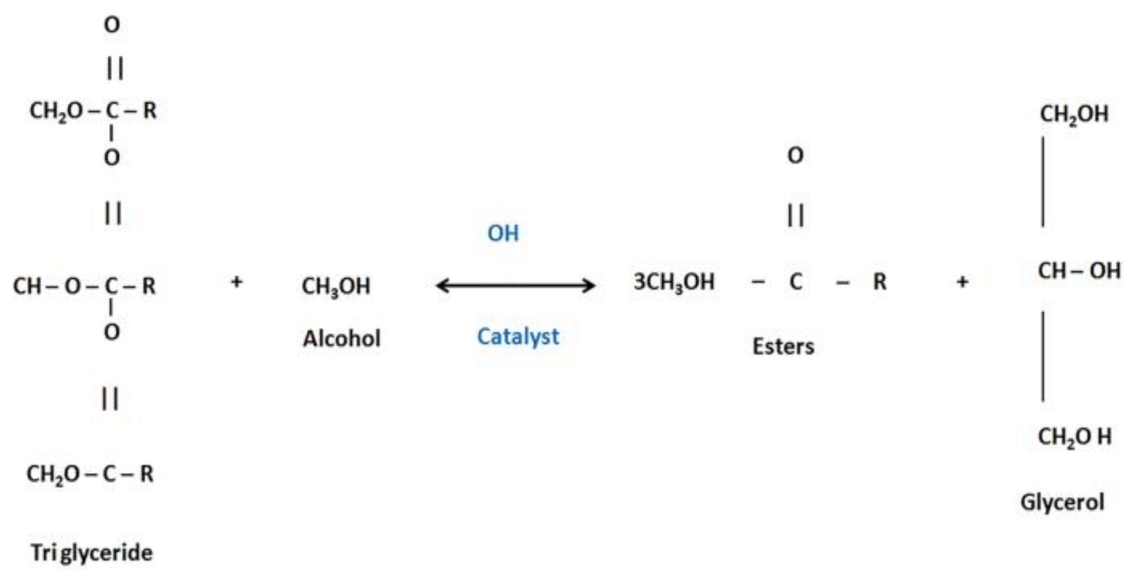


Figure 2. 1 Transesterification reaction for biodiesel production

Three fatty acids are connected to triglycerides (organic fats and oils) base and it has molecule of glycerin. Free fatty acids are formed by hydrolyzing triglycerides. After this these free fatty acids are reacting with alcohol and formed ester or biodiesel (methyl or ethyl fatty acid ester) and glycerol. due to reaction of free fatty acid with alcohol transesterification is also known as alcoholysis. The final products of transesterification process are separated, biodiesel settles on the top and due to gravity glycerol settles down. The process of separation should be very fast to avoid reverse process (Fazal M.et al.,2011). methanol and ethanol are usually used in transesterification process. If free fatty acids used methanol for reaction the transesterification process is known as methanolysis. In methanolysis process heat is applied to the mixture of methanol (10–20%) and oil (80–90%) and very less quantity of catalyst. proper mixing of free fatty acids and methanol is essential because solubility of methanol in oil is less. Biodiesel produced from the methanolysis process is fatty acid methyl ester (FAME) (Verma P. et al.,2016). For transesterification methanol was preferred because it has higher reactivity and cheaper in price than other alcohols. Free fatty acids used ethanol for reaction the transesterification process is known as ethanolysis. Ethanol is slightly increasing heat content of fuel and cetane number and also ethanol has less toxic content as compared to other alcohol

(Hajjari M. et al.,2017). There are two main issues associated with ethanolysis, the first one is the reaction required high energy and the other one is issue in separation of ester and glycerol. That's why price of biodiesel produced through ethanolysis is increased (Digambar,2020). The produced biodiesel from the ethanolysis process is fatty acid ethyl ester Produced biodiesel from transesterification process have many advantages as compare to pure plant oil (PPO). viscosity is one significant property of fuel is which directly effects engine performance. Pure plant oil has higher viscosity than biodiesel. High viscosity inversely influence the fuel injection time, atomization, and injection pressure for compression ignition engine. Characteristics of biodiesel are quite similar to petro diesel it can be used in diesel engines with small variations (Verma P. et al.,2016).

For the production of biodiesel from transesterification two approaches are followed-
(a) Catalytic Transesterification approach
(b) Supercritical Methanol Transesterification approach.

(a) Catalytic transesterification approach: Due to presence of catalyst glycerol and ester is formed when triglyceride reacts with alcohol, this approach is known as catalytic transesterification. The features of triglyceride or fat/oil defined by the nature fatty acids that means the behavior or feature of biodiesel directly influenced by nature of fatty acid (Gude V. et al.,2013). heat is applied to oil in a container to remove water content from oil. After elimination of water, oil taken inside container and again heat is applied and continuously subjected to stirring. The oil reacts with alcohol in the presence of catalyst and form a mixture at 60 °C temperature of oil, and stirring process is sustained till glycerol separation initiates. After this mixture is taken into a separate vessel and kept it in for 8 hours. After the accomplishment of reaction glycerol settles down slowly due gravity and biodiesel remain top. The separation of glycerol and ester indicate effectiveness of transesterification process. glycerol may be purified for additional usage in cosmetic and pharmaceutical industries (Digambar,2020).

(b) Supercritical Methanol Transesterification approach: In this approach instead of this two-phase mixture, single phase mixture is formed at supercritical state (pressure- 43 MPa, temperature- 340 °C). At these conditions dielectric constant of alcohol reduces. At supercritical state reaction time is very less and it is approximately 2 to 4 minutes. In this process purification of biodiesel is very easy because catalyst is not used. The main drawback of super critical transesterification process high cost of production (Hajjari M. et al.,2017).

2.7 Use of catalysts

Transesterification process is carried out in the presence of catalysts. The catalyst is used to accelerate the reaction rate and to get better quality biodiesel. The vegetable oils, used cooking oil or animal fats are reacted with alcohol in the presence of acid or base catalysts. Selection of both acid and base are made according to the characteristics of feedstock (Meher L.C. et al.,2006). The base catalysts are chosen over acid catalysts, due to their requirement of lower reaction temperature, higher conversion efficiency and their capability of completion of reaction at higher speed as compared to acid catalysts. base catalyst is can be used only when free fatty acid (FFA) is less than one and can also be used in case of Free fatty acid greater than one but higher amount of catalyst is required. Various types of base catalysts are used for the transesterification of vegetable oils. The most common among these are potassium hydroxide, potassium methoxide, sodium hydroxide and sodium methoxide. Particularly when the acid value of feedstock is high acid catalysts are used. The acid value of edible oils is normally low as compared to non-edible oils. However, the acid value of edible oils also increases when they are used for frying purpose for long time (Ejaz M. et al.,2011).

2.8 Most important variables that influence the transesterification reaction

There are different factors that influence the transesterification process of biodiesel productions. The main factors affecting transesterification are reaction time, alcohol-oil molar ratio, reaction temperature and pressure, catalyst, water content and free fatty acid content.

a) Reaction temperature

The rate of reactions is strongly influenced by reaction temperature. however, the reaction is conducted close to the boiling point of methanol (60-70 ºC) at atmosphere pressure for specified time. Though alkaline alcoholysis of vegetable oils is normally conducted near boiling point of the alcohol and that reaction can be carried out at room temperature. when the temperature exceeds the boiling point of alcohol, the alcohol will vaporize and form large bubbles which may hinder the reaction and decrease of biodiesel yield because higher reaction temperature accelerates saponification of triglycerides (Karmaker A. et al.,2010).

b) Ratio of alcohol to oil

Another important variable is the molar ratio of alcohol to vegetable oil that affecting the conversion efficiency, the yield of biodiesel as well as biodiesel production cost**.** Also, since the stoichiometric molar ratio of alcohol to oil for transesterification is 3:1 and the reaction is reversible, higher molar ratio are required to increase the miscibility and to enhance the contact between the alcohol molecule and triglyceride.

Transesterification is an equilibrium-controlled reaction in which excess of alcohol can be used to get complete conversion and alcohol is easily recoverable. moreover, increase in the amount of alcohol to oil increase biodiesel yield and biodiesel purity. Therefore, higher alcohol to oil molar ratios gives rise to greater alkyl ester conversion in a shorter time. Molar ratio is associated with types catalyst used such as; for alkali catalyzed transesterification reaction the alcohol to oil ratio is ranging 5:1 to 12:1 that are most acceptable for maximum conversion to ester. however, when using acid catalyst, the desirable maximum conversion is obtained with sulfuric acid with alcohol to oil molar ratio of 30:1. This is in line with result reported based on eat vegetables oils. A molar ratio of 6:1 is normally used in industrial process to obtain methyl esters yields higher than 98%(w/w). the molar ratio of alcohol to oil has no effect on acid value, saponification values and iodine values of esters (Carraretto C. et al.,2004).

C) Catalyst Concentration

A catalyst is used to improve the transesterification reaction and amount yield produced. Alkali metal alkoxides are found to be effective transesterification catalyst compared to acidic catalysts. The most common and efficient catalysts for biodiesel production KOH and NaOH ca also be used. A concentration in the range of 0.5-1%(w/w) has found to yield 94 to 99% conversion to vegetable oil esters and further increase in catalyst concentration does not affect the conversion but adds to extra cost, as the catalyst needs to remove from the reaction mixture after completion of reaction. In consequence, with vegetable oils or fats containing low FFA and water, the base catalyst transesterification is much faster than the acid catalyst transesterification and is most commonly used commercially on the industrial scale (Karmaker A. et al.,2010).

d) Mixing intensity

During the transesterification reaction, the reactants initially form a two-phase liquid system because oils and alcohols are not totally miscible, for this reason dynamic mixing is required to increase the area of contact between the two immiscible phases. Alcoholysis process can be enhanced by the agitation intensity of the reactor. Mass transfer of biodiesel from the oil phase towards the alcohol-oil interface might be a vigorous step that limits rate of alcoholysis reaction because the reaction is heterogenous. The mixing effect has been found to play a significant role in the slow rate of the reaction. As phase separation ceases, mixing becomes insignificant. The effect of mixing on the kinetics of the transesterification process forms the basis for process scale up and design, therefore, fast string accelerates transesterification reactions that variation in mixing strength is expected to change the kinetics of by the transesterification reactions (Carraretto C. et al.,2004).

e) Effect of Moisture and Free Fatty Acid

Sustainably, impurities in the oil affect the conversion level of crude oil to biodiesel. The free fatty acids and moisture content are the key parameters to determine the viability of vegetable oils to be used for transesterification process. The presence of moistures in the oil could increase the free fatty acids in the oil. To carry out the transesterification reaction, the free fatty acids in the oil must be less than 3%. Higher the acidity the oil, the smaller is the conversion efficiency. As little as 3% water in the reaction mixture reduced glycerol yield y consuming catalyst. Other investigators have also stressed the importance of a nearly dry oil substantially free (<0.5%) of fatty acids. High free fatty acid content oils are processed with an immiscible basic glycerol phase as to neutralize the free fatty acids and cause them to pass over the glycerol phase (Karthikeyan et al.,2014).

2.9 Properties and Qualities of Biodiesel

The properties and qualities of biodiesel must adhere with the international biodiesel standard specifications. These specifications include the American Standards for Testing Materials (ASTM6751-3) or the European Union (EN 14214) Standards for biodiesel fuel

(Digambar,2020). The properties of biodiesel are characterized by physicochemical properties. Some of these properties include; density (kg/m^3), caloric value (MJ/kg), viscosity(mm^2/s),cetane number, pour and cloud points (◦C), flash point (◦C), acid value (mg KOH/g-oil), ash content (%), copper corrosion, sulfur content ,carbon residue, water content and sediment, distillation range, glycerin (% m/m), phosphorus (mg/kg) and oxidation stability. The biodiesel physical and chemical fuel properties is basically depending on the type of feedstock and their fatty acids composition (A.E. Atabani et al.,2012).

2.9.1 Kinematic viscosity

Viscosity is the most significant property of any fuel as it indicates the ability of a fuel to flow easily at specified temperature. Viscosity affects the spray atomization and operation of the fuel injection equipment, mostly at low temperatures the fluidity of the fuel affected by viscosity. The kinematic viscosity of biodiesel is 10–15 times greater than that of diesel fossil fuels. This is because of its large chemical structure and large molecular mass. biodiesel can become very viscous or even solidified at low temperatures. Some studies thought that higher viscosity of biodiesel can affect the injection spray characteristics in the engine. The maximum allowable limit of viscosity according to ASTM D445 ranges are (1.9-6.0 mm^2/s) and (3.5-5.0 mm^2/s) in EN ISO 3104 (Xue et al.,2011).

2.9.2 Density and Relative Density

Density is the mass per unit volume. Oils that are denser contain more energy. Density should be tested at the temperature reference of 15 or 20 ˚C. Relative density is the density of the component compared to the density of water. The relative density of biodiesel is needed to make mass to volume conversions, calculate flow and viscosity properties, and is used to judge the homogeneity of biodiesel tanks (A.E. Atabani et al.,2012).

2.9.3 Flash point (FP)

Flash point of a fuel is the lowest temperature at which it will ignite when exposed to a flame. Flash point varies inversely with the fuel’s volatility. The FP of biodiesel is higher than that of diesel fossil fuel, which is safe for transport, handling and storage purpose. Conventional diesel fuel has a flash point of 55–66 ˚C, while biodiesel usually has a flash point more than 150 ˚C (Xue et al.,2011).

2.9.4. Cloud point (CP), pour point (PP) and cold filter plugging point (CFPP)

The characteristics of biodiesel at low temperature is a significant quality criterion. This is because viscous of the fuel may cause problems of starting, blockage of the fuel lines and filters, driving and engine damage due to insufficient lubrication. The cloud point is the temperature at which wax crystals first becomes visible when the fuel is cooled. Pour point is the temperature at which the amount of wax out of solution is sufficient to gel the fuel, thus it is the lowest temperature at which the fuel can flow. Commonly, biodiesel has higher Cloud point and Pour Point compared to petro diesel.

Cold filter plugging point (CFPP) refers to the temperature at which the test filter starts to plug due to fuel components that have started to gel or crystallize. It is a commonly used as indicator of low temperature operability of fuels and reflects their cold weather performance. At low operating temperature fuel may thicken and might not flow properly affecting the performance of fuel lines, fuel pumps and injectors (A.E. Atabani et al.,2012).

2.9.5. Titer

The temperature at which oil changes from solid to liquid known as Titer. Titer is significant because the transesterification process is fundamentally a liquid process, and oils with high titer may need heating, which enhance the energy requirements and costs of production for a biodiesel plant (Karmaker A. et al.,2010).

2.9.6. Cetane number (CN)

The cetane number (CN) is ability of fuel to auto-ignite quickly after being injected or the indication of ignition characteristics. Better ignition quality of the fuel is always related with higher cetane number value. CN is one of the most important parameters, which is considered during the selection procedure of methyl esters for using as biodiesel. Increasing saturation and increasing chain length of fatty acids, increases cetane number. A higher CN indicates shorter time between the ignition and the initiation of fuel injection into the combustion chamber.

Biodiesel has higher combustion efficiency, because it has higher cetane number than conventional diesel fuel (A.E. Atabani et al.,2012).

2.9.7. Oxidation stability (OS)

Oxidation stability is an indicator of the degree of oxidation, potential reactivity with air, and can assess the need for antioxidants. The oxidation of biodiesel fuel is one of the major factors that helps to determine the quality of biodiesel. Oxidation happens due to the occurrence of unsaturated fatty acid chains and the double bond in the parent molecule, which directly react with the oxygen as soon as it is being exposed to air. The chemical composition of biodiesel fuels makes it more susceptible to oxidative degradation than the conventional diesel (Petro-diesel) fuel (A.E. Atabani et al.,2012).

2.9.8. Lubrication properties

The lubrication properties of the biodiesel are better than conventional diesel, which can help to increase the engine, but they can contribute to the formation of deposits, cold flow properties, plugging of filters, depending mainly on degradability, glycerol and other impurities content. high lubricity of biodiesel might result in the decreased friction loss and thus enhance the brake effective power (A.E. Atabani et al.,2012).

2.9.9. Acid value

Acid number (neutralization number) is a measure amount of free fatty acids exist in a fuel sample. FFAs are the saturated or unsaturated monocarboxylic acids that exist naturally in fats, oils or greases but are not attached to glycerol backbones. Fatty acids vary in carbon chain length and in the number of unsaturated bonds (double bonds). Higher amount acid value is due to higher amount of free fatty acids. Acid value is expressed as mg KOH required for neutralizing 1 g of FAME. In fuel supply system of an engine severe corrosion is result of high acid value in free fatty acid of diesel and biodiesel fuels (Karmaker A. et al.,2010).

2.9.10. Heating value and Carbon residue

Heating value or heat of combustion is the amount of heating energy released by the combustion of a unit value of fuels. moisture content of the feedstock oil is the one of the most important determinants of heating value.

Carbon depositing tendencies of the fuel after combustion is indicated by carbon residue. Carbon residue for biodiesel is more significant than that in conventional diesel fuel because it indicates a high relationship with presence of free fatty acids, higher unsaturated fatty acids, polymers, glycerides, inorganic impurities and soaps (A.E. Atabani et al.,2012).

2.9.11. Free glycerin

Free glycerin refers to the quantity of glycerol that is left in the complete biodiesel. The amount of free glycerin in biodiesel is dependent on the production process. The high yield of glycerin in biodiesel may be caused from insufficient separation during washing of the ester product. glycerol is easily removed by settling because glycerol is essentially insoluble in biodiesel. Free glycerol may remain either as the very small amount that is dissolved in the biodiesel or as suspended droplets. High free glycerol can damage to the fuel injection and cause injector coking (A.E. Atabani et al.,2012).

2.10 Biodiesel Specifications

The America society for testing and materials international (ASTM) specification for biodiesel (B100) is ASTM D 6751-02. Also, the European standard (EN 14214) is accepted by all member states of the European committee for standardization of biodiesel(B100). A number of the test methods listed in it perform over one role. These ways measure that the fuel performs same as supposed in CI engines and as tests to confirm that the manufacturer produced a high quality B100[25]. Every of those properties and the test process used to measure it are in brief represented below in Table 2. 1

Table 2. 2 Specifications of biodiesel according to ASTM standards (A.E. Atabani etal.,2012).

Properties of biodiesel	Units	ASTM D-6751		EN 14214	
		Limits	Test methods	Limits	Test methods
Kinematic viscosity (40ºC)	mm^2/s	1.9-6.0	D445	3.5-5.0	EN ISO 3104
Density(15ºC)	Kg/m^3	N/S	N/S	860-900	EN ISO 3675
Ester content	mass%	N/S	N/S	96.5 min	EN 14103
Cetane number	-	47 min	D613	51 min	EN ISO 5165
Flash point	ºC	130 min	D93	120 min	ISO/CD 3679
Water content	volume%	0.050 max	D2709	500 max	EN ISO 12937
Sulphated ash	mass%	0.020 max	D874	0.02 max	ISO 3987
Copper corrosion	grade	No.3 max	D130	No.1	EN ISO 2160
Acid number	mg KOH/g	0.80 max	D664	0.5 max	EN 14104
Iodine number	-	N/S	N/S	120 max	EN 14111
Oxidative ability (110ºC)	H	N/S	N/S	0.8 max	EN 14112
Oxygen content	%	N/S	N/S	N/S	N/S
High calorific value	MJ/kg	N/S	N/S	N/S	N/S
Free glycerol	mass%	0.020 max	D6584	0.02 max	EN 14105
Total glycerol	mass%	0.240 max	D6584	0.25 max	EN 14105
Phosphorous content	mass%	0.001 max	D4951	10 max	EN 14107

2.11 Fuel Additives

Additives are organic based or metal-based substances which are easily soluble in fuel and its main purpose is to improve, maintain, and provide beneficial characteristics to the fuel without affecting the performance and combustion parameters. The fuel additives are added in smaller quantities ranging from 100 ppm to several thousand ppm. At present for vehicular fuels, combustion of numerous chemical additives is used to improve the quality of biodiesel fuel and diesel fuel to convene up the most wanted performance level. Additives will help out the petroleum to recover its engine combustion, performance and emission environmental standards. Therefore, fuel additives in diesel, biodiesel and their blends improve the fuel characteristics the additives selection will be based upon the drawbacks of biodiesel fuel such as density, toxicity, viscosity, economic feasibility, additives solubility, auto ignition temperature, flash point, and cetane number for the fuel blending process. The fuel additives are broadly classified as Metal based additives, Oxygenated additives, Cetane number improver additives, Antioxidant additives, Ignition promoter additives, Lubricant additives etc. (K. Mishra et al.,2018).

a) Metal-Based Additives

Metals and metal oxides enhance the burning characteristics of the fuel when added to the fuel in the range of micro- or nano sizes through ppm (percentage by weight ratios). Metals like aluminum (Al), magnesium (Mg), iron (Fe) ,manganese (Mn), boron (B), silver (Ag), silica (Si), gold (Au), copper (Cu), graphene, etc., and metal oxides like aluminum oxide (Al_2O_3), cerium oxide (CeO_2), zinc oxide (ZnO), cobalt oxide (Co_3O_4), titanium oxide (TiO_2), copper oxide (CuO) etc., are used as additives to improve the fuel physiochemical properties. metals alloys like Carbon nanotubes (CNT) and magnalium (Mg-Al) are also used as metal-based additive which also used as performance enhancers of fuels by changing its physiochemical properties (K. Mishra et al.,2018).

b) Oxygenated Additives

Oxygenated components like biodiesel, ethanol, methanol, dimethyl ether, dimethyl carbonate, diethylene glycol diethyl ether, etc., are used as an additive to improve the burning characteristics of fuel with more ignition delay, chemical compounds having more oxygen content are added to that fuel at a trivial quantity. which easily mixes and blends with conventional diesel fuel (K. Mishra et al.,2018).

c) Additives to Improve Cold Flow Behavior

During cold conditions, the wax content exist in the biodiesel starts to freeze and results in crystal-like structure which affects the cold filter plug point (CFPP). This condition may be avoided by using additives like glycerol ketals, ethylene vinyl acetate copolymer, glycerol acetates, succinimide copolymers, and phthalimide which improves the cloud point property of the fuel (K. Mishra et al.,2018).

d) Additives to Improve Cetane Number

Cetane number is one of the main properties of fuel which determines the fuel quality or the ignition capability of the fuel. Diesel engine provides better performance with high cetane number of fuels. additives which improve the cetane number of the fuel are nitro carbonates, nitrates, nitroalkanes, peroxides, etc. (K. Mishra et al.,2018).

e) Antioxidants

Biodiesels produced by transesterification process which are ready to react with oxygen by the process called auto-oxidation. To avoid auto-oxidation of biodiesel in the petro diesel blend, additives like TBHQ (Tert-butyl hydroquinone), BHT (Butylated hydroxytoluene), BHA (Butylated hydroxyanisole), PA (Pyrogallol) and PG (Propyl gallate) are mixed with petro diesel–biodiesel blends (K. Mishra et al.,2018).

2.12 Nano-Particles as Additives

Addition of some metal and metal oxide in the form of nano-powder to the base fuel may enhance the properties of the fuels. This is due to the interesting properties of nanoparticles like higher specific surface area, thermal conductivity, catalytic activity and chemical properties as compared to their bulk form. Moreover, nano-particles as additives in diesel as well as biodiesel as new hybrid fuel blends. The properties of nano-particles such as size, thermal conductivity and chemical properties affect the performance and emission characteristics of engine. Reduced size of the nano-particles increased specific surface, surface to volume ratio, and surface area improving catalytic reactivity and magnetic properties as compared to their bulk form. Hence metal and metal oxide nano-particles addition to biofuel will improve the performance as well as reduce the harmful gases from engine exhaust. Addition of cerium oxide nano-particles to biodiesel may also be effective as they enhanced surface area to volume ratio. Flash point of biodiesel, which is an indication of the volatility, was found to increase with the inclusion of such additives making them safer fuels. The viscosity of biodiesel was found to increase with the addition of cerium oxide nano-particles to biodiesel. The viscosity and the volatility were found to hold direct relations with the dosing level of the nano-particles (K. Mishra et al.,2018). Therefore, nano-particles can function as both catalyst and an energy carrier when used in base fuels in diesel engines. In addition, small scale of nano-particles, also facilitate stability of fuel suspensions when used with base fuels (Aydin Huseyin et al.,2010).

Nano particle blending

The process of adding nanoparticles to the fuel is done with the aid of an ultrasonicator. The ultrasonicator technique is the best suited method to disperse the nanoparticles in the base fuel, as it facilitates possible agglomerate nanoparticles back to nanometer range. The required quantity of the nanoparticle for each sample was accurately measured using a precision electronic balance and was mixed with the fuel by means of a probe sonicator, passing ultrasonic waves for a time period of 30 minutes to produce a uniform suspension. The modified fuel was utilized immediately after preparation, in order to avoid any settling or for sedimentation to occur (K. Mishra et al.,2018).

2.13 Summary of related works

A number of researchers have investigated on biodiesel. Most of them concluded that biodiesel can be carefully burned for short periods of time in a diesel engine. Nevertheless, using biodiesel in a diesel engine for long times may result in injector coking, severe engine buildup and increases in viscosity of the lubricating oil. The high thickening of raw oil decreases fuel atomization and raises fuel spray penetration. Higher spray dispersion is thought to be partly responsible for the problems experienced with engine accumulation and increases in viscosity of the lubricating oil. These effects can be reduced through transesterification eliminates glycerol from the triglycerides. Several researchers have investigated that the exhaust emission is influenced by the use of biodiesel.

2.13.1 Performance and Emission Characteristics of cotton seed oil Biodiesel Fuels

Huseyin Hasan et al., (2011) mentioned that the maximum power difference between petro diesel fuel and Cotton seed oil methyl ester (cotton seed oil biodiesel) blends were enhanced with an enhance in the amount of cotton seed oil methyl esters. The brake specific fuel consumption of B20 at full engine speed was found to be lower than petro diesel fuel. For B50, B75, and B100, minimum carbon monoxide emissions were investigated. However, in the experimental investigation, the NOx emissions were reduced for all blends except B5.

Ali Ahmad., (2009) carried out an experimental study on a single cylinder, direct injection–type compression ignition engine using cotton seed oil biodiesel blends with diesel as an alternative fuel. Concluded that the engine torque and engine power output with biodiesel-diesel fuel blends decreased by 5.8% and 6.2% respectively. Depending on the amount of bio-diesel and engine speeds, specific fuel consumption values with fuel blends increased by 10.5%.

Murat Kadir et al., (2012) Investigated the performance and emission of diesel engine fueled with cottonseed oil biodiesel-diesel fuel blends with addition of various fractions of diethyl ether (DEE) as an oxygenated fuel additive. Primarily, numerous tests carried out for B20 blend. Then, 2.5%, 5%, 7.5%, and 10% of DEE by volume was mixed with biodiesel-diesel fuel to prepare the ternary blends. All the fuel samples were run on in a single-cylinder, four-stroke, and direct-injection compression ignition engine at five different engine loads and fixed engine speed conditions. The experimental results showed that brake thermal efficiency was reduced by 17.39% while increasing in brake specific fuel consumption by 29.15% for 10% addition of DEE in the blend as compared to diesel fuel. Besides, the engine fueled with ternary blends revealed mitigation up to 4.12%,8.84% and 12.89%, in the smoke, NO_X and HC emissions, on an average, respectively than those of diesel fuel. CO emission showed increasing tendencies with the diesel fuel at higher proportions of DEE despite up to 40.09. The CO_2 also decreased under high loads. However, the combustion behaviors vaguely deteriorated when the CI engine run on all ternary blends. concluded, DEE can be removing the main issues with the usage of cottonseed oil biodiesel.

Md. Nurun Nabi et al., (2011) Investigated the performance and emission of diesel engine fueled with cottonseed oil biodiesel. Biodiesel mixtures showed less PM, CO, smoke emissions than those of conventional diesel fuel. NOx emission with biodiesel mixtures showed higher values when compared with conventional diesel fuel. Compared to the conventional diesel fuel, 10% biodiesel mixtures reduced smoke emissions, particulate matter by 14% and 24%, respectively. Biodiesel mixtures (30%) reduced carbon monoxide emissions by 24%, while 10% enhance in the NOx emission was experienced with the same blend. The reason for increasing NOx emission and decreasing three emissions (PM, smoke and CO) with biodiesel mixtures was mainly due to the presence of oxygen in their molecular structure. Also, low aromatics in the biodiesel mixtures may be an additional reason for reducing these emissions. Thermal efficiency with biodiesel mixtures was slightly lower than that of conventional diesel fuel due to lower heating value of the mixtures. However, higher viscosity, volatility, higher density may be additional reasons for efficiency reduction with biodiesel mixtures.

R. Anand et al., (2014) investigated the performance and emissions of a variable compression ratio diesel engine fueled with cotton seed oil biodiesel. bsfc of pure diesel was found minimum as compared to biodiesel blends at all loads. At lower compression ratios (15:1, 17:1) B5 has minimum SFC and at compression ratio of 19:1, B20 has least bsfc compare to diesel fuel. At 15: 1 compression ratio, the BSFC is enhanced by 2.5% and 4.92% for the B5 and B20 blends. BSFC is increased by 3.5% for both the B5 and B10 blends at 17:1 compression ratio, whereas at 19:1 compression ratio, the B20 blend suggests slightly better fuel economy. The BTE was found to increase with increase in compression ratio and there is no big difference in BTE of biodiesel blends and pure diesel. However, maximum thermal efficiency at high loads B5 was at compression ratio 15:1 and B20 at compression ratio 19:1. At compression ratio 17:1, B5 and B10 have nearly equal efficiencies at full load. The maximum BTE values vary between 27.37- 29.28% for cotton seed biodiesel- diesel blends and 26.65-27.92% for pure diesel fuel.

A. Siva Kumar et al., (2009) investigated the performance and emission from neat and transestrified cotton seed oil. The results showed cotton seed oil biodiesel has higher kinematics viscosity and flash point, lower thermal efficiency and low aromatics.

Md.Nurun Nabi et al., (2009) The study shows that the smoke emissions, carbon mono oxide, particulate matter of cotton seed oil biodiesel are less than diesel fuel but it increases NOx emissions. Thermal efficiency with biodiesel mixtures was slighter lower than that eat diesel fuel because of lower heating value of mixtures.

Marta Zeleke (2016) tested the performance and emission of cotton biodiesel in diesel vehicles. The result showed pure biodiesel was not used because it is found that viscosity of cotton seed biodiesel is higher than that of Petro diesel. The torque and power performance get reduced and fuel consumption increased as the percentage of biodiesel in the blends increased. The biodiesel blends produced lower emissions in CO, CO_2 and HC emission while NO_X and O_2 emissions are show on little increment compared to the conventional diesel fuel.

Zinabu Atnafu (2017) observed engine performance fueled with B20(20% cotton seed biodiesel and 80% diesel) with addition of ethanol 5%,10% and 15%. The result gained the power and torque performance produced get reduced and the fuel consumption increased as the percentage of ethanol increased. concluded that ethanol 5% and 10% are most applicable.

2.13.2 Effect of Nanoparticle Additive on performance and emissions

Debas Dessie (2019) investigated on the performance and emission characteristics of diesel-biodiesel blend with nano additive in CI engine. Brake power of the engine when fueled with B20 was lower than that of pure diesel but brake power of B20+50ppm Al_2O_3 and B20+50ppm CeO_2 was increased due to addition of nano additive. Brake torque for B20, B20+50ppm Al_2O_3 and B20+50ppm was lower than pure diesel. BSFC of B20 was higher than B20+50ppm Al_2O_3 and B20+50ppm CeO_2. Emission of CO, CO_2 and HC of B20, B20+50ppm Al_2O_3 and B20+50ppm CeO_2 was lower than that of neat diesel. Concluded addition of Al_2O_3 and CeO_2 nano additives are improved the performance and characteristics of a DI diesel engine.

Geremew Birbirsa (2017) studied properties of addition of Ceo_2 NPs in argemone Mexicana biodiesel blended with Petro diesel fuel. It was concluded that cerium oxide nanoparticles improve the combustion, performance and emission characteristics as additive in biodiesel blende without any engine modification.

A. Kandasamy et al., (2017) investigated on the performance and emission characteristics of a diesel engine fueled with cotton seed oil biodiesel with addition of titanium oxide nanoparticles. The test conducted with blend of diesel and biodiesel blends BN20 and BN40 at different loads. The result shows diesel and biodiesel blend enhanced combustion and decreased the exhaust gas emissions due to addition of titanium oxide nanoparticles.

C.Srinidhia et al., (2019) evaluated the effects of iron nanoparticles (INP) blended palm biodiesel (PB) on the performance and emission characteristics of diesel engine, an experimental investigation is conducted in a single cylinder diesel engine. Methodically, palm oil used for production biodiesel and used iron NPs as additive in this study. Iron NPs are mixed in the biodiesel in proportions of 40 ppm to 120 ppm using an ultrasonicator. The complete study is carried out in the diesel engine using diesel, PB20, INP50PB30, and INP75PB30 fuel samples. The adding of nanoparticles additive has resulted 3% of BTE and 3.3% of BSFC was increased compared to baseline diesel fuel. The emission levels of CO by 56% and NO_X by 4% are significantly decreased with the addition of iron nanoparticles. Increase of iron nanoparticles in the blend from 50 ppm to 75 ppm, BTE and BSEC tend to reduce, but CO and NO_X emissions are reduced.

A. Selvaganapthy et al., (2013) studied the zinc oxide nano additive added to diesel shows the cylinder peak pressure and rate of heat release increased and ignition delay reduced, due the presence of particles and the addition of Al_2O_3 and CuO decreases BSFC but also reduces NOx emissions.

T. Shaaf et al., (2015) used ethanol, isopropanol and aluminum oxide as fuel additive for 20% biodiesel of soybean and 80% diesel blend. They blended 100 mg/l of AONP in D80SBD15E4S1 blend, and noticed a severe reduction in viscosity and calorific value along with an increase in Cetane number and analyzed the influence of nanoparticle additives with 20% biodiesel of soybean and 80% diesel blend in the diesel engine. Alumina nanoparticles along with ethanol and isopropanol (surfactant) were mixed with diesel-biodiesel blend. The amount of NOx was same up to 50% load for diesel and nano blended fuel and beyond that it increased than neat diesel. UBHC was very high by 25% than neat diesel and B20, and it was increasing uniformly as the load was increased.

C. Syed Aalam et al., (2015) investigated on common rail direct injection system aided diesel engine using diesel blended with Iron (II, III) Oxides NPs. The iron (II, III) Oxide NPs was blended with diesel in mass fraction of 25ppm and 50 ppm by using homogenizer and an ultrasonicator. The investigation was carried out with the objective of gaining relative measures of combustion and emission parameters to assess the behavior of the common rail direct injection diesel engine running on the diesel and iron (II, III) Oxide NPs blended modified diesel. It was perceived that iron (II, III) Oxide NPs blended diesel exhibit a significant reduction in specific fuel consumption and exhaust emission at all operating loads. The results also showed a significant enhancement in brake thermal efficiency and heat release rate due to influence of iron (II, III) Oxide nanoparticles addition in diesel.

Soner Gumus et al., (2016) investigated formulated by sonicating nano particles of boron (B) 80-100 nm, iron (Fe) 5-150 nm and aluminum (Al) having 30-60 nm in size in base diesel with 0.5wt% and 0.1wt% Span80 as a surfactant for stable suspension. The nano fuels decreased ignition delay, longer flame sustainable and agglomerate ignition by droplet combustion mechanism test. Peak cylinder pressures reduced at higher load conditions.

Anand et al., (2015) mentioned that the addition of 30 ppm Al_2O_3 and CeO_2 with Jatropha biodiesel enhanced the kinematic viscosity, density and calorific value as 4.25 Cst,875 kg/m3 and 38.9 MJ/kg for JBD30A blend. JBD30C blend was found to have similar fuel property values as 4.30 Cst,876 kg/m3 and 38.7 MJ/kg respectively. The addition of aluminum oxide with Jatropha biodiesel improved the thermophysical fuel properties and combustion process of the fuel.

Karthikeyan (2014) studied the influence of addition of ZnO nano particles in palm oil biodiesel. It was concluded that the ZnO NPs additives blends showed slightly enhancement in calorific value and kinematic viscosity. No significant difference was observed in flash point, pour point, cetane number and sulphated ash due to the addition of ZnO.

Abbas A Bafghi et al., (2015) studied the effects of CeO_2 nanoparticle adding in Diesel and Diesel Biodiesel blends. The experiments showed that CeO_2 NPs was used as additive in diesel and diesel/biodiesel blends to enhance complete combustion of the fuel significantly. The major observations, an enhancement tendency for the flash point with the dosing level.

H. K. Imdadul et al., (2015) a comprehensive review on the assessment of fuel additive effects on combustion behavior in CI engine fueled with diesel biodiesel blends. Addition of additives in diesel, biodiesel and their blends have a great effect on fuel properties such as viscosity, flash point, fire point, pour point, calorific value etc. which in turns influences the combustion parameters. Metal-based additives such as $FeCl_3$, CON, CNT, alumina nanoparticles showed an increased in HRR, CGP and PP with earlier start of combustion and decreased ignition delay.

Arockiasamy et al., (2015) studied addition of Al_2O_3 and Ceo_2 nanoparticles as additives in Jatropha biodiesel. Al_2O_3 and Ceo_2 nanoparticles were added to the biodiesel using ultrasonicator. Both blends were stable without any phase separation up to 48 hrs. BTE increased up to 5% for both the samples. JBD30A displayed 33% reduction in UBHC ,9% reduction in NOx, 20% reduction in CO and 17% reduction in smoke opacity than neat biodiesel. JBD30C displayed 7% reduction in NOx, 28% reduction in UBHC, 20% reduction in CO and 20% reduction in smoke opacity than neat biodiesel.

Tayfun Ozgur et al. (2015) studied effect of nanoparticle additives on NOx emissions of diesel fueled compression ignition engine. $ZnNiFe_2O_4$ diesel blends NOx variations 25, 50 and 100 ppm ZnNiFe2O4 nanoparticle addition decreased the NOx emissions of all blends. The maximum NOx emission reductions were found 15%, 19.3% and 22.5% with 25, 50 and 100 ppm ZnNiFe2O4 addition to diesel fuel respectively. The maximum NOx emission reduction was obtained at 1,200 engine speed for the all blends. The average reductions were 5.1%, 9.2% and 12.6% with 25, 50 and 100 ppm respectively.

2.14 Summary of Literature Reviews

A number of researchers have investigated on effect of nanoparticles in biodiesel. Most have concluded that nanoparticle additive is playing a magnificent task in increasing the performance of the diesel engine, improving the combustion and reducing the emissions. A metal-based additive will reduce the pour point, viscosity and enhance the flash point properties of biodiesel fuel. The bsfc decreases significantly due to their catalyst effect by adding the metal-based additives. Most of them are done their work on biodiesel by adding nanoparticle like Al_2O_3, Al, ZnO, Fe and CeO_2 and investigated on diesel engine fueled with cotton seed oil biodiesel with addition of this nanoparticles. But still it is not investigated on diesel engine fueled with cotton seed oil biodiesel with addition of three elemental (Nickel, Zinc and Iron oxide) nanoparticles as additives.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials

The cotton seed oil was obtained from Addis Modjo Edible Oil Share Company. Methanol and potassium hydroxide were bought from FIRMAMENT TRADING PLC chemical selling and suppliers' company in Ethiopia and Nickel Zinc Iron oxide nanoparticles was obtained from nanoscience in India for laboratory scale amount. All chemicals used for this study were analytical grade.

Additional materials and equipments were used for this study are beaker, separating fuel, flask, reactor, hotplate with magnetic stirrer, measuring cylinder, digital balance, thermometer, protective equipment, distilled water, diesel fuel, 4-stroke diesel engine and engine dynamometer. Materials and equipments used for study are listed in Table 3.1, Table 3.2 and Table 3.3.

Table 3.1. List of materials required for the study

No	Item	Unit	Quantity
1	Cotton seed oil	Liter	5
2	KOH	Gram	300
3	Methanol	Liter	1
4	Nickel Zinc Iron oxide nanoparticles	Gram	1
5	Distilled water	Liter	100
6	Aluminum foil	Inch	4
7	Diesel fuel	Liter	10

Table 3.2. List of equipment required for the study

No	Item	Unit	Quantity
1	Conical flasks	Pcs	6
2	Hot plate with magnetic stirrer	Pcs	3
3	Beakers (different sizes)	Pcs	6
4	Thermometer	Pcs	1
5	Digital Balance	Pcs	1
6	Ultrasonic cleaner	-	1
7	Glass ware	Pcs	2
8	Glove	Pcs	2
9	Fuel flow meter	Pcs	1
10	Stand funnel separators	Pcs	3

Table 3.3. List of equipment required for testing sample

No	Item
1	Engine dynamometer
2	4-stroke diesel engine
3	Exhaust gas analyzer

3.2 Methods of the study

The method of the study was small scale laboratory production of biodiesel from cotton seed oil, methanol as reactant and potassium hydroxide catalyst through transesterification process. Characterization fuel samples tested at Ethiopian petroleum supply enterprise while the performance and exhaust emission tested at Department of Mechanical Engineering work shop of Dilla University, Dilla, Ethiopia on CT 110 Test Stand Diesel Engine.

This study was done mainly based on experimental activities. The methods and procedure used in this thesis work were following:

- Cotton seed oil collected from Addis Modjo Edible Oil Share Company.
- Transesterification reaction.
- Blending biodiesel and petro diesel with additive Nickel Zinc Iron oxide nanoparticle using ultrasonicator.
- Preparation of blends of fuel with additive for characterization.
- Characterization of pure biodiesel and biodiesel-petro diesel blends with additive Nickel Zinc Iron oxide nanoparticle using different parameters.
- Preparation of blends of fuel with additive for performance test set up.
- Perform the performance and exhaust emission tests of biodiesel-petro diesel blends with nanoparticle in diesel engine.
- Comparing the test result from biodiesel-petro diesel blends with nanoparticles additive according to performance parameters with petro diesel fuel.

The cotton seed oil was obtained from Addis Modjo Edible Oil Share Company. Methanol and potassium hydroxide were bought from FIRMAMENT TRADING PLC chemical selling and suppliers' company in Ethiopia and Nickel Zinc Iron oxide nanoparticles are obtained from nanoscience in India. Transesterification reaction and blending biodiesel and petro diesel was done in laboratory of chemistry department of ASTU. Blending biodiesel and petro diesel with additive Nickel Zinc Iron oxide nanoparticle was done in laboratory of Material Engineering department of ASTU. Performance and exhaust emission tests were carried out in Mechanical Engineering workshop of Dilla University.

This study was carried out based on the following experimental procedures shown in the Figure 3.1.

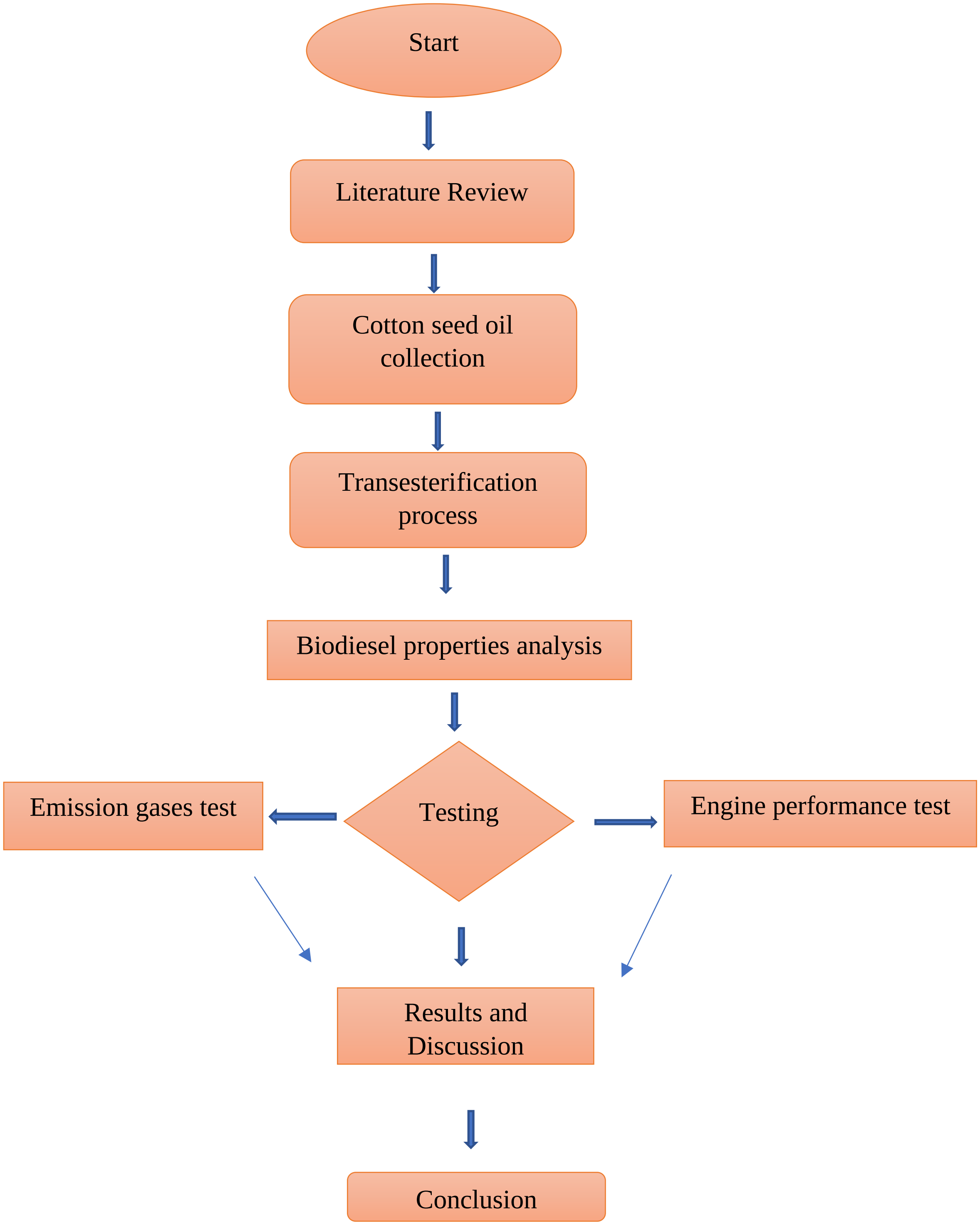


Figure 3.1. Flow chart of methodology

3.3 Transesterification of cotton seed oil

The Transesterification process of cottonseed oil was making triglycerides of cotton seed oil to react with methyl alcohol (methanol) by using Potassium hydroxide (KOH) as catalyst to produce biodiesel and glycerol. This process was performed at Chemistry department laboratory of Adama Science and Technology University, Adama, Ethiopia.

Step by step the transesterification process of producing cotton seed oil biodiesel is mentioned below:

1. Firstly, the required cotton seed oil was prepared, then 500ml cotton seed oil was measured and poured in beaker and heated to temperature of 60°C (Figure 3.2).

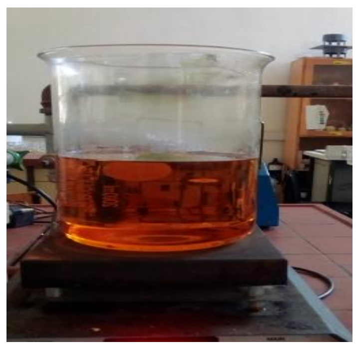


Figure 3.2. Preheating of the oil

2. 100ml of methanol and 5gm of Potassium hydroxide (KOH) were measured to prepare the solution of potassium methoxide. The molar ratio of methanol to catalyst is 20:1. Then, shake the mixture until the KOH was fully dissolved in methanol (Figure 3.3).

a b

Figure 3.3. (a) KOH and methanol and measured KOH and methanol (b)

3. After Potassium hydroxide (KOH) was fully dissolved in methanol, the potassium methoxide solution poured into heated oil and the dissolved mixture was stirred with 1000 rpm stirrer speed for 1 hour at fixed temperature of 60°C. During this process the cotton seed oil and the potassium methoxide solution was covered by Aluminum foil to prevent escaping of methanol during process because its boiling point closer to 60-65 °C (Figure 3.4).

Figure 3.4. Heating the mixtures of KOH and methanol with oil

4. When the reaction time reaches 40 minutes glycerin starts to separate and settle at bottom and a clear solution appears at the top.
5. After the reaction is finished the products were poured into separating fuel and hanged for 24 hours. Then two phases layer formed, the lower layer consists of glycerol and soap due to gravity and the biodiesel formed at the top (Figure 3.5). Then removing the glycerol and collecting the biodiesel

Figure 3.5. Separation of biodiesel and glycerol

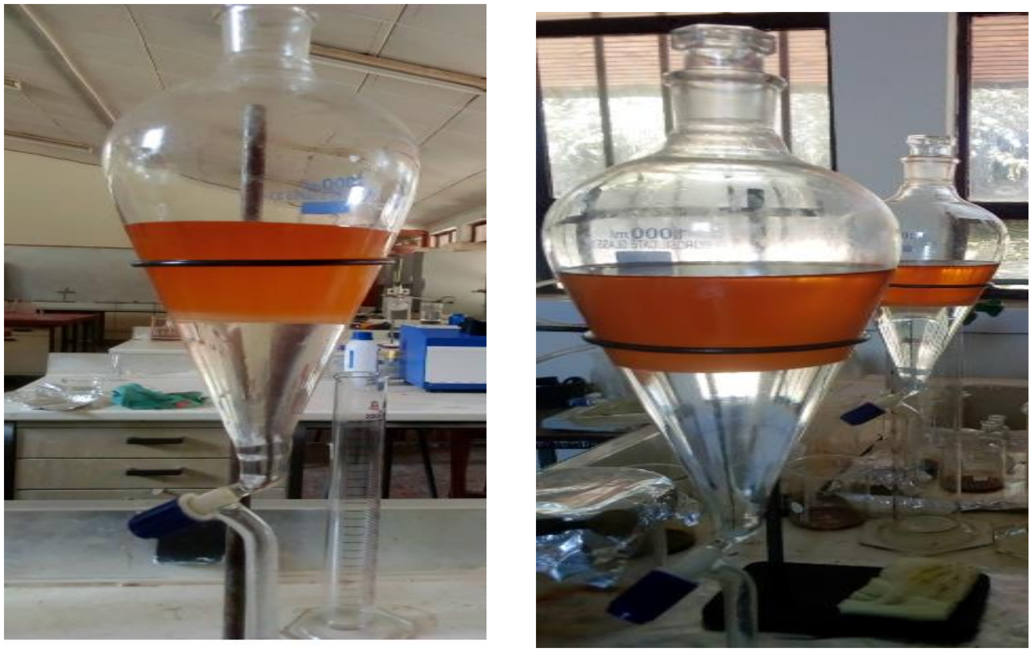
6. The next step was washing of biodiesel with the hot distilled water that was heated at 55 $^{\circ}$C and the water equivalent to half volume of biodiesel. biodiesel washing was used to remove any excess of glycerol, soap, alcohols and catalyst that may be left in the biodiesel. This was done until the water is mostly clear that would see the biodiesel in the separating funnel in Figure 3.6 (final washing).

First washing

Second washing

Third washing

Fourth washing



Fifth washing Final washing

Figure 3.6.Washing of biodiesel

7. Finally, the washed biodiesel was dried by placing on the hot plate for 1 hour about 140 $^{\circ}$C to remove remaining alcohol and water in the biodiesel. Figure 3.7 shows biodiesel before drying and after drying.

a) Before drying b) after drying

Figure 3.7.Drying of biodiesel

8.After washing, the final pure biodiesel was collected and yield of biodiesel was calculated. Generally following all the step by step listed above pure biodiesel was produced. shown in Figure 3.8.

Figure 3.8. The final collected pure biodiesel

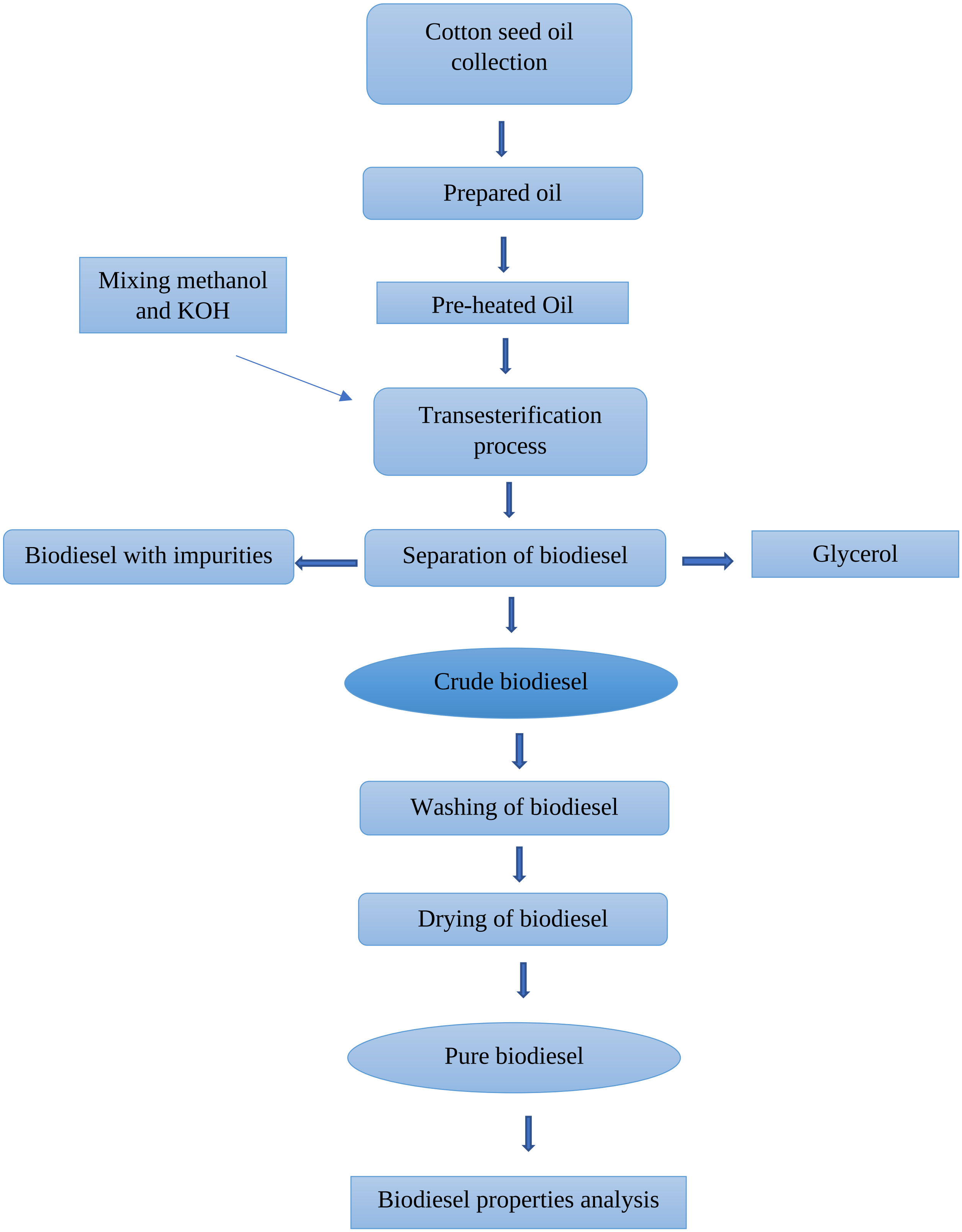


Figure 3.9.Conceptual flow chart of overall biodiesel production from cotton seed oil

3.4 Biodiesel blend preparation

As it is known a lot of research work has already been carried out to use vegetable oil both in a pure form and also blend forms. Studies show that the usage of vegetable oils in its pure form is possible but it preferable as the blended one. because, biodiesel can be blended with any proportion B5(5% biodiesel and 95% petro diesel fuel) to B20(20% biodiesel and 80% petro diesel fuel) being the most common one. Many researchers mentioned biodiesel blends at a range of B20 and lower range can work on engine without modification. For this study the cotton seed oil biodiesel mixed with petro diesel fuel in form of B20(20% biodiesel and 80% petro diesel fuel) shown in Figure 3.10.

Steps of blending diesel and biodiesel fuel (B20)

- ✓ Firstly, measure 800 ml of diesel using 1000 ml beaker
- ✓ Measure 160 ml (20% of diesel by volume) of biodiesel using 500 ml beaker
- ✓ Pour the 800 ml diesel into 1-liter bottle.
- ✓ Finally, the 160 ml biodiesel was poured in to the 1-liter bottle and shake it at least for 2 minutes.

a b

Figure 3.10.(a) Measured diesel and biodiesel and (b) Diesel-biodiesel blend

3.5. Nano-biodiesel fuel blends preparation

For this study biodiesel produced from cotton seed oil by transesterification method. The fuel additive used in this investigation is Nickel Zink Iron oxide nanoparticles, in the form of commercially available nanoparticles of size 10 to 30 nanometers and purity of 99.5%. the dosing of the Nickel Zink Iron oxide nanoparticles samples (by weight) in the blended fuel was varied with 25 ppm,50 ppm and 100 ppm.

Materials and equipment used for nano-biodiesel fuel blends preparation

a) **Nickel Zink Iron oxide nanoparticles:** 10 to 30 nm, 99.5% was used for enhancing performance and reduction of exhaust emissions. The detailed specifications of Nickel Zink Iron oxide nanoparticles are shown in Table 3.4.

Table 3.4. Specifications of Nickel Zink Iron oxide nanoparticles

	Parameters	Nickel Zink Iron oxide nanoparticles
1	Manufacturer	Nano Research Lab (India)
2	Chemical Name	$NiZnFe_2O_4$
3	Molar Mass	411.46 g/mol
4	Average particle size (APS)	10-30 nm
5	Morphology	nearly spherical
6	Color	Dark brown
7	Bulk density	0.80 g/cm^3
8	True density	5.2 g/cm^3
9	Density	2.81 g/cm^3
10	Purity	99.5%

b) Cetyletrimethyl ammonium bromide (CTAB): is quaternary ammonium acts as a cationic surfactant. Surfactant play a key role in nanoparticles synthesis by adsorbing to the surface of the forming nanoparticles, lowering its surface energy and help to prevent collection. It forms an envelope on the surface of the particle and makes the surface as a negative charge, the particle sedimentation was controlled.

c) Analytical Precision balance: It is sometimes known as electronic balance designed to measure small mass in the sub-milligram range. They use an electromagnet to generate a force to counter the sample being measured and output the result by measuring the force the needed to achieve balance (0.00001 gm) weighing a liquid, powder or granular substance at high accuracy and optimum performance and large easy to read display.

Analytical Precision balance feature

- Fast stabilization in 2 seconds
- One-touch automatic calibration
- Rotary sliding doors
- Front-mounted spirit level
- Removable breeze break

Analytical Precision balance specification

- Weighting capacity: 252g/0.1mg
- Weighting pan size: 90mm

d) Ultrasonic cleaner: It is a machine used for blending nanoparticles with diesel or diesel-biodiesel blends. ultrasonic cleaning is process uses ultrasound (usually from 20-40KHz) to agitate fuel and to produce a uniform suspension.

A) nanoparticles B) Cetyletrimethyl ammonium bromide

C) Ultrasonic cleaner D) Electronic balance

Figure 3.11. Materials and equipment used for nano-biodiesel fuel blends preparation

Steps of preparation and blending of nanoparticles are discussed as followed.

- Measure 100 ml diesel-biodiesel blend (B20) and poured into the 500 ml beaker.
- Measure 0.025 gm, 0.05 gm and 0.1 gm of Nickel Zink Iron oxide nanoparticles for B20+25ppm, B20+50ppm and B20+100ppm respectively.
- Measure 0.025 gm, 0.05 gm and 0.1 gm of CTAB for B20+25ppm, B20+50ppm and B20+100ppm respectively.
- Then, the measured nanoparticles and CTAB were poured into the first measured 100 ml diesel-biodiesel blend (B20) fuel containing beaker and stirred at least for 15 minutes.
- The 100 ml nanoparticles dispersed diesel-biodiesel blend fuel solution was poured into the 900 ml diesel-biodiesel blend (B20) containing bottle.
- Finally, after preparing the sample it was mixed with an ultrasonic cleaner for a time period of 30 minutes with a high frequency level to produce a uniform suspension. Figure 3.12 below shows blending of diesel-biodiesel with nanoparticles using ultrasonicator.

Figure 3.12.Ultrasonicator sated at high frequency

3.6 Characterization of the cotton seed biodiesel and diesel-biodiesel blend

Characterization is the process of determining physiochemical properties of petroleum products and non-petroleum products like biodiesel and diesel-biodiesel blends. Before testing the engine performance and exhaust emissions it is very important to check physiochemical properties of biodiesel and diesel-biodiesel blends. These are density, kinematic viscosity, cloud point, calorific value and total acidity.

Fuel prepared for characterization is B100 (pure biodiesel), B20 (80% Petro diesel and 20% biodiesel), B20+25ppm (80% Petro diesel and 20% biodiesel with addition of 0.025gm of nanoparticles), B20+50ppm (80% Petro diesel and 20% biodiesel with addition of 0.05gm of nanoparticles) and B20+100ppm (80% Petro diesel and 20% biodiesel with addition of 0.1gm of nanoparticles) are shown Figure 3.13.

The above-mentioned physiochemical properties of B100, B20 and B20+100ppm were performed in quality control laboratory of Ethiopian petroleum Supply and Enterprise while physiochemical properties of B20+25ppm and B20+50ppm were performed in chemistry laboratory of Adama Science and Technology University (ASTU), Adama, Ethiopia.

Figure 3.13. Biodiesel and diesel-biodiesel blend ready for characterization

3.6. 1 Determination of density (ASTM D4052)

Density is a fundamental property that can be used in conjunction with other properties to characterize both light and fractions of petroleum products. Determination of the density of petroleum and its products is necessary for the conversion of measured volumes to volumes at the standard temperature of 15ºc or 25ºc.

Digital Density Analyzer: - digital density analyzer consists of U-shaped, oscillating sample tube and a system for electronic excitation, frequency counting and display. The analyzer shall accommodate the accurate measurement of the sample temperature during measurement. Introduce a small amount (about 1 to 2 ml) of sample into clean, dry sample tube of the instrument using a suitable syringe.

Ensure that sample tube is properly filled and that no gas bubbles are present. The sample must be homogeneous and free of even the smallest gas bubbles. After the instrument display a steady reading to four significant figures of density, relative density, API gravity or both as appropriate. If the two determinations do not differ more than 0.0002g/mol for density, average the two determinations otherwise discard both determinations and repeat the analysis using two new test specimens until the acceptance criteria identified above is satisfied. In reporting density, state the test temperature and the units (for example: density at 15ºc is 0.8459 g/mL or

845.9 Kg/m^3). The final result report for density is four significant figures (Hajjari M. et al.,2017).

3.6.2 Determination of cloud point (ASTM D2500)

The cloud point of petroleum product is the temperature at which wax crystals first becomes visible when the fuel is cooled. Mixtures commonly used for temperature reduction are the following: -

- Ice and water up to 10ºC
- Crushed ice and sodium chloride up to negative 12ºC
- Crushed ice and calcium chloride up to negative 26ºC

The cloud point was determined by virtually inspection for haze in the normally clear fuel, while the fuel was cooled under carefully controlled conditions. The sample was continuously monitored and the temperature (ºC) that corresponds to the formation of first cloud the fuel was recorded (Hajjari M. et al.,2017).

3.6.3 Determination of kinematic viscosity (ASTM D445)

Kinematic viscosity of biodiesel, biodiesel blended and with fuel additive was determined using ASTM D445, standard test method for kinematic viscosity of transparent and opaque liquids. Cannon-Fenske glass capillary viscometer tube was used in a SETA KV-8 viscometer bath. The liquid in the bath heated to 40ºC, sample fuel is filled in the capillary viscometer tube and inserted in the bath and kept for 30 minutes to maintain an equilibrium of bath temperature. The time (t) is recorded for a fixed volume of liquid to flow under gravity through the capillary of calibrated viscometer. kinematic viscosity is then calculated as the product time(t) in second and the calibration constant (K) of the viscosity tube (Hajjari M. et al.,2017).

$$\text{Kinematic viscosity} = K \times t \qquad (3.1)$$

Where, k is the calibration constant for viscometer in (mm^2/s), t is time in second

3.7 Experimental Test Setup

Engine performances and emissions of exhaust gas test were carried out in the department of Mechanical and Vehicle Engineering workshop of Dilla University, Dilla, Ethiopia on CT 110

Test Stand, Small Combustion Engine consists of single cylinder, air cooled and diesel engine connected to asynchronous motor which is operated as a dynamometric brake for loading. Table 3.5 displays the technical specification of the CT 110 test stand for small combustion Engine.

The setup enables the evaluation of thermal performance and emission constituents of the engine. The thermal performance parameters include brake power, brake torque and brake specific fuel consumption. The CT 110 Test Stand for Small Combustion Engines facilitates experiments on combustion engines on the consumption of air for combustion and fuel consumption. In addition, measured values on the speed and load behavior of the engines under test are provided. Apart from the CT 110 test stand, a functional experimental setup must include atleast one engine (e.g. CT 100.32). Once the engine is placed in test stand, experiments for plotting engine performance can be performed. For this purpose, the combustion engine is connected to the synchronous motor, which is operated as a dynamometric brake. The brake unit is an air-cooled asynchronous motor with a regenerative feedback unit. The torque and speed are generated by way of a frequency converter. The regenerative feedback of the braking energy into the system provides for highly energy-efficient operation of the test stand. The torque is measured by means of a suspended brake unit and force sensor. The engine is mounted on a vibration-insulated base plate and connected to the asynchronous motor. The mass of the base plate in conjunction with the soft bearing support ensures that the test stand runs very smoothly, so there is no need for a solid foundation. The asynchronous motor is initially used to start the engine. As soon as the engine is running, the asynchronous motor and regenerative feedback unit act as a brake unit for applying a load to the engine. The braking power is fed back into the electrical system. The lower section of the mobile frame contains fuel tanks and a quietening vessel for the intake air. The air consumption is measured by way of a measuring nozzle. The fuel consumption is measured by way of the level in the vertical pipe. The switch cabinet contains digital displays for the speed, torque and temperatures (one display for engine cooling water inlet and outlet and one display for exhaust gas, fuel and intake air). Pressure gauges indicate negative intake pressure and air consumption. The measured values are transmitted directly to the desktop computer via USB. The data acquisition software is included. The well-structured instructional material sets out the fundamentals and provides a step-by-step guide through the experiments. Apart from measurements on the consumption of fuel and combustion air, the test stand for small combustion engines is used in experiments to measure the torque and speed on the engines employed. The relevant measured values are indicated on clear displays. The schematic of the CT 110 Test Stand for Small Combustion Engine test setup was found on Appendix-A

The setup also includes the necessary measuring instruments for the measurement of exhaust gas emissions. The exhaust emissions of the engine are analyzed by using an exhaust gas analyzer. The constituents of the exhaust gas like CO, CO_2, HC and O_2 are measured with exhaust gas analyzer.

Table 3. 5. The CT 110 Test Stand for small combustion engine specification

S.no	The CT 110 Test Stand for small combustion engine specification and technical data	Dimensions
1	Engine Model	1B30-2
2	Length x Width x Height	370 mm x 330 mm x 450 mm
3	Numbers of cylinder	single cylinder
4	Company	Hatz
5	Weight approx.	35 kg
6	Fuel	CT 100.22 Diesel
7	Bore	80 mm
8	Stroke	69 mm
9	Crank length	34.5 mm
10	Rod length	114.5 mm
11	Output power at 3500 rpms	5.5 kW
12	Oil capacity	1.1 L
13	Stop solenoid	12 V
14	Compression ratio	22: 1
15	Engine type	Air-cooled single cylinder 4-stroke Diesel Engine

Table 3.6 Specification of the Asynchronous motor for CT 110 Test Stand

Specification ad technical data	Dimensions
Power output	7,5 kW at 2900 rpm
Regenerative feedback unit	13 kW
Measuring ranges for torque	-50 to 50Nm
Measuring ranges for speed	0 to 5000 rpm
Fuel consumption	50 cm^3/min
Engine intake pressure	-400 to 0 mbar
Air consumption	0 to 690 L/h
Weight	approx. 245kg
Length x Width x Height	1450 x 850 x 1880 mm
connections	400V, 50/60Hz, 3 phases

3.8 Exhaust gas analyzer (Infralyt smart)

The Infralyt smart modular gas analyzer has been specially designed and manufactured to accurately measure specific gas components of the exhaust of petrol engine vehicles (with or without catalyst) in any situation where the composition needs to be determined it can be used for:

- General vehicle servicing
- Statutory testing to the prescribed limits
- Emissions enforcement
- Training and tuning engines

The Infralyt smart equipped with an integrated revolution counter and oil temperature measuring device can be used to:

- Accurately monitor the CO levels and air-fuel ratio (lambda) prescribed by legislation.
- Carry out rapid fault diagnosis on engines using the composition of the exhaust gas and other measurable factors.
- To analyses the fuel mixture
- To assist with ignition timing and valve adjustment

- To measure engine speed and oil temperature on 2 and 4 stroke engines using a variety of probes/sensors. The detailed specification of exhaust gas analyzer was shown in Table 3.7.

Table 3.7 Specification of CT 159.02 Infralyt smart exhaust gas analyzer

Specification and Technical Data	Dimensions
Carbon monoxide	0 - 10% vol
Carbon dioxide	0 - 20% vol
Hydrocarbon	0 - 2500ppm vol.
Lambda	0 - 999
Oil temperature	0 - 130°C
Accuracy classes	1 and 0
Working temperature	5 - 45°C
Length x Width x Height	330 x 260 x 205mm
Weight approx.	7 kg
Operating voltage and frequency	230V, 50/60Hz, 1 phase or 120V, 60Hz, 1 phase

During experiments, the test stand is used to display torque, speed, and various temperatures and to perform consumption measurements for combustion air and fuel on the engine being tested. The desktop computer connected engine test measures the output results of engine performance and gas analyzer records output emission test. The total output measurements were mechanical efficiency, thermal efficiency, brake power, brake torque, brake fuel specific consumption, exhaust gas etc. but on this thesis work, the output measurements were only exhaust gas, brake power, brake torque and brake fuel specific consumption.

3.9 Experimental Procedure

- Firstly, prepare all materials that used for experimental test and to adjust the CT 110 test stand diesel engine.
- The flow of air, the level of lubricating oil and all connections between the engine and the test stand are checked before starting the engine.

- Connect CT 110 test stand diesel engine to the mains electricity sources. The air hose and exhaust hose must be connected, and the outlet of the exhaust hose must be outdoors
- The engine is fitted with a temperature sensor cable to measure the exhaust gas temperature. For this purpose, the combustion engine is connected to the asynchronous motor in the CT 110, which is operated as a braking device. All tests were subjected to full loading.
- Before starting the engine, the fuel line to the engine and the measuring tube on the CT 110 test must be filled.
- Start the engine using the braking device in the CT 110 with the asynchronous motor operating as a starter motor.
- Turn on the ignition and asynchronous motor by pressing their button on the CT 110 test stand.
- Allow the engine to run without load for approximately 5 minutes to ensure warm and steady operating conditions.
- The test was start with pure diesel fuel (B0) and followed by poured biodiesel-diesel blended sample (B20, B20+25ppm, B20+50pmm and B20+100ppm) into the fuel tank step by step to test and record accuracy result on output.
- Set the speed for the asynchronous motor and torque by adjusting their knob on the CT 110 test stand.
- When the C engine starts up, turn off the asynchronous motor with the “starter/brake” button.
- Full and partial load characteristic curves are to be recorded on the engine.
- The measurement time is about 10 sec of the full load (for the stabilization of speed and result reading) for each measurement point (an individual value of speed).
- The experiment result was conducted, and recorded through on desk top computer with exhaust analyzer displayed.
- Each time when the diesel-biodiesel blend samples were changed the engine was run with diesel fuel for few minutes to wash the fuel lines.
- For accuracy of the measurement the test was repeated two times for each tested fuel samples.

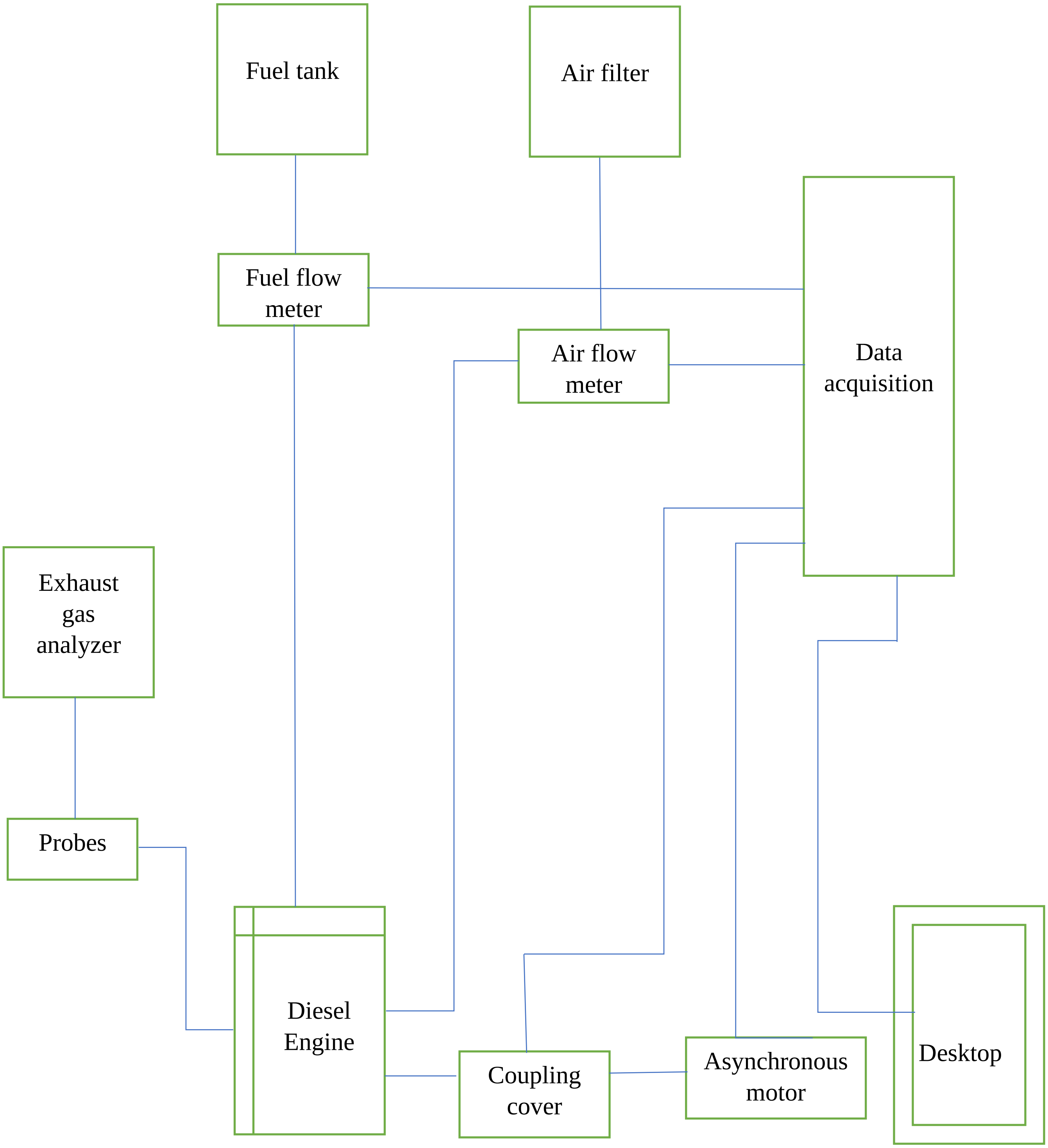


Figure 3.14. Schematic view of experimental set up

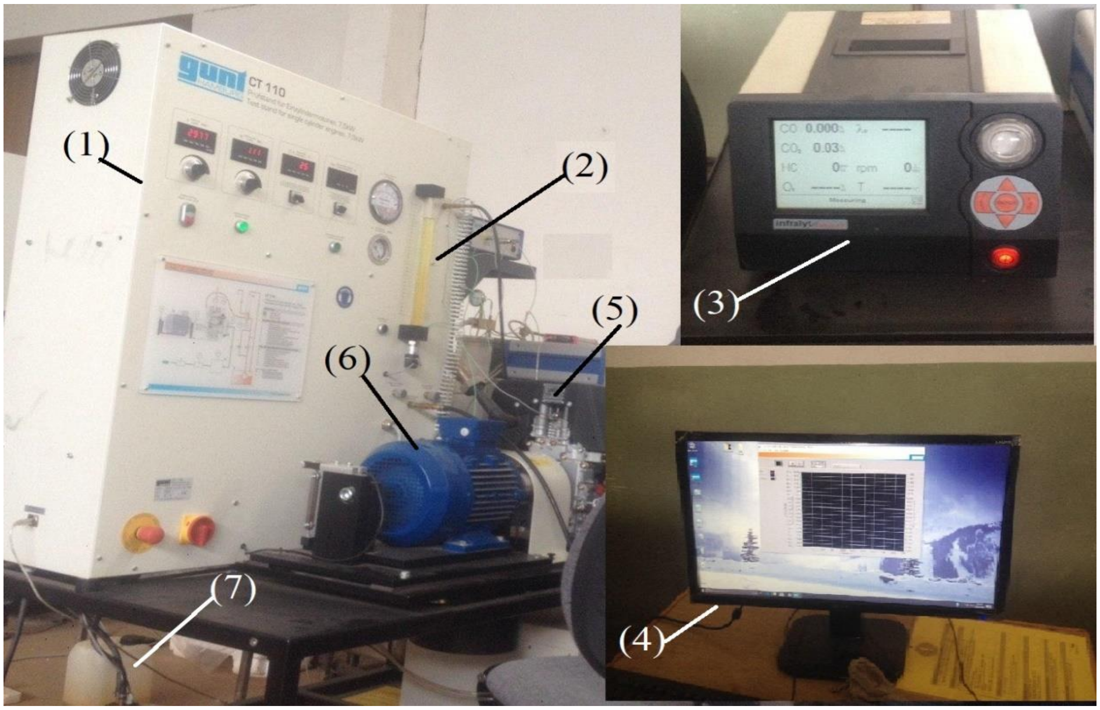


Figure 3.15. Photographic view of experimental set up

(1) Test stand (CT 110)	(4) Desktop computer
(2) Fuel flow meter	(5) Diesel engine (CT 100.32)
(3) Exhaust gas analyzer (CT 159.02)	(6) Asynchronous motor, (7) Fuel tank

3.10 Experimental Test Matrix

An experimental test matrix is the number of tests that were being executed and guidance for experimental work. Table 3.8 shown the experimental test matrix for diesel-biodiesel blends.

Table 3.8. Diesel -biodiesel blend experimental test matrix

Engine operating parameters		Engine speed	Diesel – biodiesel blend	Evaluating Engine Parameters
	Fixed CR, IP and IT			
Constant engine load and Varying engine speed	Set fixed as factories recommender	2000rpm	B0	A) Performance parameters ➢ Brake power ➢ Brake torque ➢ Brake specific fuel consumption B) Emission parameters ➢ CO ➢ CO_2 ➢ HC ➢ O_2
		2200 rpm		
		2400 rpm	B20	
		2600 rpm		
		2800 rpm	B20+25ppm	
		3000 rpm		
		3200 rpm	B20+50ppm	
		3400 rpm	B20+100ppm	

3.11 Data Analysis

From the experiment test stand for small combustion engine exhaust gas, brake torque, brake fuel specific consumption, and brake power data were directly collected from recorded through on the desk top computer with exhaust analyzer displayed. These data were tabulated in accordance with specified engine speed and converted into brake power and brake torque of the engine relative to the engine speed.

a. **Brake power (Pb):** is the net power available at the output shaft or flywheel (at crank shaft). The output power can be calculated and can be plotted as a curve on a graph for the different speeds. To record the output power curve related to the full load characteristic curves, with the engine running the speed regulator is set to the maximum amount fuel. Using the dynamometer on the CT 110 test stand, the engine is then loaded by turning the speed potentiometer to maximum (Willard W.2002).

$$Pb = M_L \times 2\pi \times n \qquad (3.2)$$

Where: Pb= Brake power(kW), n=engine speed(rpm) and M_L= engine load

b. Brake Torque (Tb): is the torque available at the output shaft' of the engine or 'Flywheel' (Willard W.2002)**.** By reducing the speed set on the potentiometer in steps, torque values are displayed on the CT 110 test stand from which the output power curve can be drawn up.

$$T_b = \frac{60 \times Pb}{2\pi \times N} \qquad (3.3)$$

Where: T_b= Brake Torque, Pb= Brake power(kW) and N=engine speed (rpm)

c. Brake specific fuel consumption (Bsfc): is the amount of fuel consumed by the engine in kilogram per hour (kg/h) to generate a brake power of one kilowatt (kW). Since the measurement was taken by volumetric flow rate, mass flow rate of the fuel was obtained by multiplying with its density. Adjusted using the speed potentiometer on the CT 110 test stand whilst the engine load is 0(torque display at 0). The load on the engine is then increased in evenly spaced steps using the speed regulator on the engine whilst the speed is maintained constant, i.e. the speed is readjusted on the test stand. Measured values for the fuel consumption are recorded; the consumption is measured at the measuring tube on the test stand using a stopwatch. For each value set for torque, the time that it takes until the liquid level drops from one mark to the next is measured on the stopwatch (1 cm drop on the scale corresponds to 5.1 cm^3 fuel consumed). The conversion is performed using the formula (Willard W.2002):

$$bsfc = \frac{\dot{m}f}{Pb} \qquad (3.4)$$

Where: *bsfc*= Brake specific fuel consumption(kg/kWh), *mf*=mass flow rate of fuel and

Pb= Brake power(kW)

3.12 Measurement of Exhausts Emissions

The substances which are emitted to the atmosphere from any opening of the exhaust part of the engine are called as exhaust emissions. If combustion was complete and the mixture is stoichiometric the product of combustion would consist of carbon dioxide (CO_2) and water and water vapor only. However, there is no complete combustion of the fuel and hence the exhaust gas consists of variety of components such as carbon monoxide (CO), unburned hydrocarbons (UBHC) and nitrogen oxides (NOx). But the measurement of NOx is not included in this work due to the engine test of NOx installation problem.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Biodiesel Yields

The biodiesel production was done by transesterification process using methanol and KOH. During the transesterification reaction the methanol to oil molar ratio and methanol to KOH was 1:5 and 20:1 respectively**.** After washing and drying the final pure biodiesel was collected and yield of biodiesel obtained was 85%. The amount of biodiesel obtained and byproducts of biodiesel production in one liter of cotton seed oil is listed Table 4.1**.**

Table 4.1. Amount of raw material needed and the amount of final product obtained.

Oil	Quantity used (ml)	Methanol used (ml)	KOH used (gm)	Biodiesel obtained (ml)	Byproducts obtained (ml)	Biodiesel Yield (%)
Cotton seed	1000	200	10	850	350	85

4.2 Characterization Result

Characterization was done to know the properties of the biodiesel produced whether it satisfies the ASTM standards for biodiesel to testing its performance in the existing diesel engine without any modification. The characterization results of the biodiesel produced from cotton seed oil and blend fuels that were certified from Ethiopian petroleum supply enterprise and chemistry laboratory results shown in the Table 4.2. From Table 4.2, the density of B100 was increased while B20, B20+25ppm, B20+50ppm and B20+100ppm were decreased. These density results were similar within the range given by Europe standard (EN 14214). The viscosity of B100 was within the range given by ASTM standards (D6751) and the viscosity of B20, B20+25ppm, B20+50ppm and B20+100ppm were nearly same with diesel fuel also satisfies ASTM standards (D6751). The cloud point of B20 was decreased while addition of nanoparticles increased. In addition to this cloud point was increased in all cases as compared with diesel fuel. In generally when we conclude these properties of biodiesel produced and blends fuels found with the range or obeying ASTM standards (D6751) and Europe standard (EN 14214).

Table 4.2. The properties of biodiesel produced and blend fuels

Sn.	Fuel Properties	Test method ASTM	BD limits	Test fuel measured value				
				Pure biodiesel B100	B20	B20+25 ppm	B20+50 ppm	B20+100 ppm
1	Density @15°C(g/mL)	D4052	Report	0.8886	0.8459	0.8459	0.8457	0.8456
	Density @20°C(g/mL)	D4052	Report	0.8851	0.8424	0.8424	0.8422	0.8421
2	Calorific value **(**BTU/LB)	Calculated	-	19,172.6	19,556.9	-	-	19,559.6
3	Cloud point(°C)	D2500	-	+10	+1	-	-	+12
4	Kinematic viscosity@40°C(cSt)	D445	-	5.2829	3.1871	3.1834	3.1797	3.1725
5	Total acidity(mgKOH/g)	D974	-	0.890	0.3667	-	-	0.340

4.3 Engine performance characteristics Vs engine speed (rpm) Graph

Engine performance characteristics Vs engine speed (rpm) Graph establishes performance test results. However, the graph also provides engine performance characteristics Vs engine speed (rpm) Graph concise explanation of each engine movement of performance and characteristics. The engine performance was measured in terms of brake power, brake torque and brake specific fuel consumption by using the formula given in chapter three (equation 3.2,3.3 and 3.4). In this section performance of all blends and emissions test results were compared with standard diesel fuel.

1.Engine Brake Power (kW): The brake power obtained at different speeds for all fuels from the CT 110 test stand diesel engine is given in Table 4.3.

Table 4.3.The output brake power data recorded from CT 110 test stand diesel engine

Engine Brake Power (kW)					
Engine Speed (rpm)	Fuel Sample				
	B0	B20	B20+25ppm	B20+50ppm	B20+100ppm
3400	4.87	4.66	4.79	4.91	4.98
3200	4.74	4.5	4.51	4.77	4.82
3000	3.99	3.96	4.02	4.15	4.22
2800	3.55	3.42	3.71	3.93	3.94
2600	3.34	3.22	3.36	3.45	3.55
2400	3.28	2.95	2.88	3.07	3.14
2200	3.12	2.62	2.62	2.71	2.82
2000	3.02	2.42	2.55	2.53	2.58

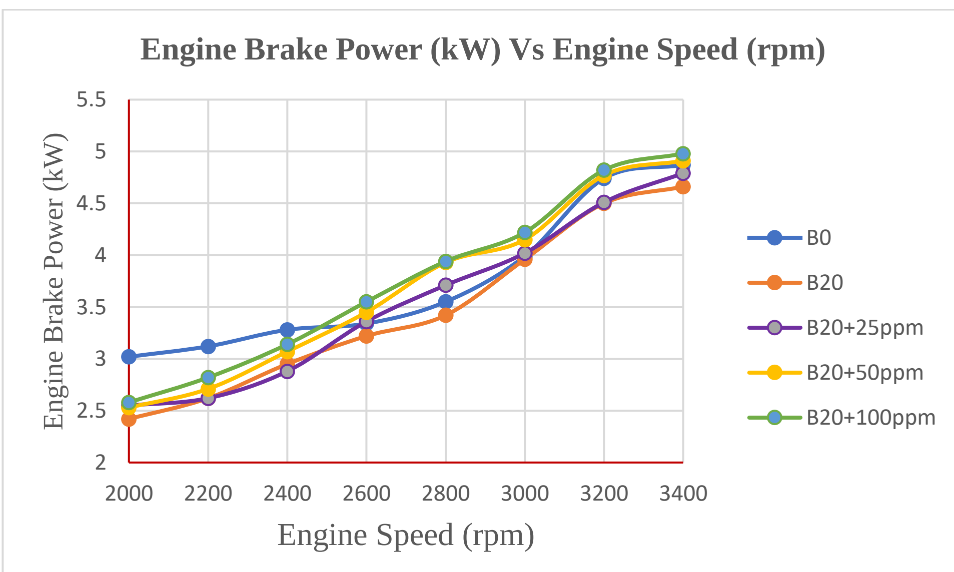


Figure 4.1.Variation of Engine Brake Power (kW) with Engine speed (rpm) at full load

From above Figure 4.1 it is observed that at lower engine speed the brake power is lower, but as the engine speed increased the brake power was also increased. The maximum brake power produced by diesel (B0) fuel sample is 4.87 kW at engine speed of 3400 rpm. Almost this thesis work is validating with previous work studied by Abbas Alli et.al.,2015. The maximum brake power for all fuel samples were observed at engine speed of 3400 rpm. At this speed the highest value of brake power for B0, B20, B20+25ppm, B20+50ppm and B20+100ppm were 4.86 kW,4.66 kW, 4.79 kW, 4.91 kW and 4.98 kW respectively. Also, at this point the highest value of brake power was obtained from B20+100ppm, this may be is due to addition of Nickel Zinc Iron oxide ($NiZnFe_2O_4$) nanoparticles. From this graph it is understand that diesel-biodiesel blend fuel with $NiZnFe_2O_4$ (B20+100 ppm) additive had more brake power than that of B20+25ppm and B20+50ppm $NiZnFe_2O_4$.

2. Engine Brake Torque (Nm): By reducing the speed set on the potentiometer in steps, torque values are displayed on CT 110 test stand from which the output power curve can be drawn up. Table 4. 4 shows the output brake torque data recorded from CT 110 test stand diesel engine.

Table 4.4. The output brake torque data recorded from CT 110 test stand diesel engine

Engine Brake Torque (Nm)					
Engine Speed(rpm)	Fuel Sample				
	B0	B20	B20+25ppm	B20+50ppm	B20+100ppm
3400	14.29	14.10	14.25	14.32	14.38
3200	13.4	13.2	13.32	13.39	13.42
3000	12.70	12.34	12.62	12.72	12.84
2800	12.06	11.66	12.14	12.25	12.37
2600	11.85	11.23	11.87	11.92	11.97
2400	12.02	11.36	11.78	12.25	12.41
2200	11.35	11.05	11.25	11.30	11.34
2000	11.30	10.75	11.25	11.29	11.30

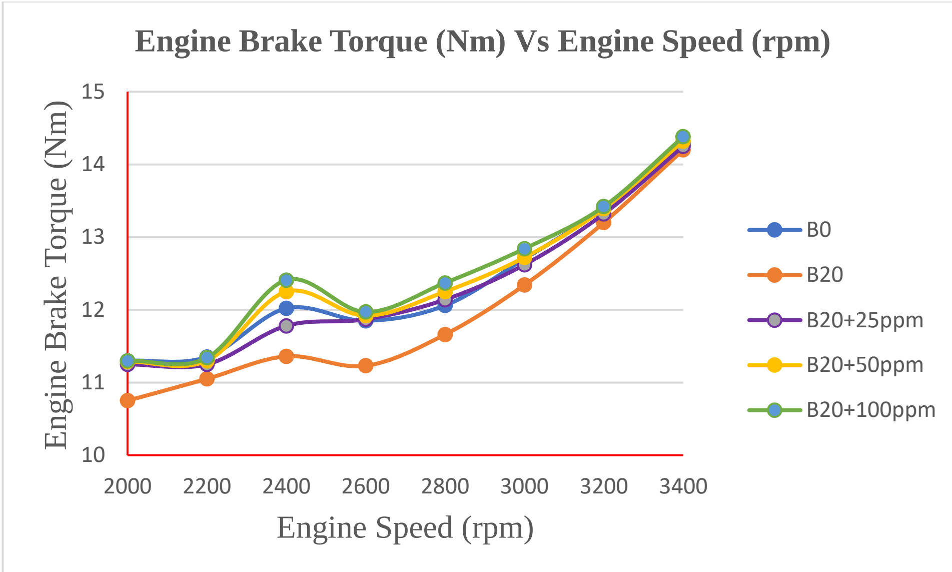


Figure 4.2.Variation of Engine Brake Torque (Nm) with Engine speed (rpm) at full load

From above Figure 4.2 it observed that at lower engine speed the brake torque is lower, but as the engine speed increased the brake torque was also increased. Almost this thesis work is validating with previous work studied by Abbas Alli et.al.,2015. The maximum brake torque produced by diesel (B0) fuel sample is 14.29 Nm at engine speed of 3400rpm. The maximum brake torque for all fuel samples were found at engine speed of 3400rpm. At this speed the highest value of brake power for B0, B20, B20+25ppm, B20+50ppm and B20+100ppm were 14.29 Nm,14.10 Nm, 14.25 Nm, 14.32 Nm and 14.38 Nm respectively. Also, at this point the highest value of brake torque was obtained from B20+100ppm, this may be due to addition of Nickel Zinc Iron oxide ($NiZnFe_2O_4$) nanoparticles. From this graph we have to understand that diesel-biodiesel blend fuel with $NiZnFe_2O_4$ (B20+100ppm) additive had more brake torque than that of B20+25ppm and B20+50ppm $NiZnFe_2O_4$ as compared.

3. Brake Specific Fuel Consumption (kg/kWh): The brake specific fuel consumption of diesel engine depends mainly on the relationship between the volumetric fuel injection, fuel density, and energy content. Table 4.5 below shows that the output data recorded from CT 110 test stand diesel engine.

Table 4.5. The output bsfc data recorded from CT 110 test stand diesel engine

Brake specific fuel consumption (bsfc kg/kWh)					
Engine Speed(rpm)	Fuel Sample				
	B0	B20	B20+25ppm	B20+50ppm	B20+100ppm
3400	0.867	0.875	0.874	0.863	0.835
3200	0.854	0.866	0.855	0.842	0.832
3000	0.809	0.818	0.817	0.805	0.801
2800	0.649	0.712	0.672	0.612	0.575
2600	0.617	0.682	0.639	0.602	0.553
2400	0.608	0.617	0.579	0.574	0.531
2200	0.719	0.745	0.65	0.61	0.67
2000	0.731	0.762	0.655	0.618	0.677

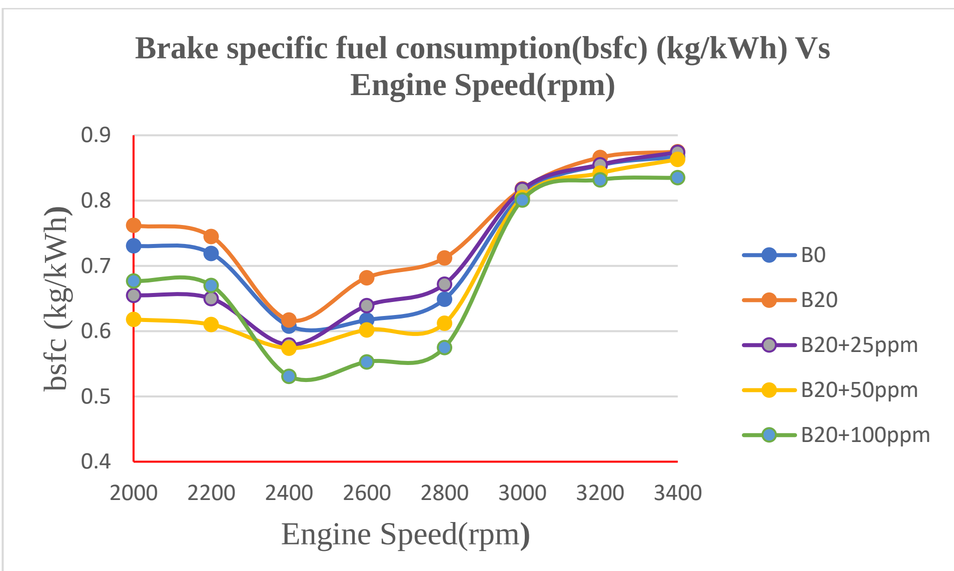


Figure 4.3.Variation of bsfc (kg/kWh) with Engine speed(rpm) at full load

From above Figure 4.3 the graph shows at lowest engine speed (2000 rpm) the brake specific fuel consumption was high. At engine speed of 2200 rpm, the brake specific fuel consumption was decreased. At engine speed of 2400 rpm, the lowest bsfc was obtained, however as engine speed increasing from 2600 rpm the bsfc was smoothly increased. Almost this thesis work is validating with previous work studied by Abbas Alli et.al.,2015. At engine speed 2400 rpm the brake specific fuel consumption of B0, B20, B20+25ppm, B20+50ppm and B20+100ppm were 0.608 kg/kWh, 0.617 kg/kWh, 0.579 kg/kWh, 0.574 kg/kWh and 0.531 kg/kWh respectively. Also, at this point the lowest value of brake specific fuel consumption was obtained for B20+100ppm. From this graph it observed that at all speed the bsfc of B20 fuel sample was higher than that of other fuel sample, this is due to the fact the B20 has lower heating value than other fuel sample. Addition of Nickel Zinc Iron oxide ($NiZnFe_2O_4$) (+25ppm, +50ppm and +100ppm) nanoparticles was decreased the value of brake specific fuel consumption. The bsfc of +100ppm is observed to be less compared to that +25ppm, +50ppm and B0 fuels.

4.4 Results from Exhaust Emissions Tests

In this section the result of emission recorded from the CT 110 test stand diesel engine was given in tabular form and also graphical form. The main emission test discussed were carbon dioxide (CO_2), carbon monoxide (CO), hydrocarbon and oxygen (O_2).

1.Carbon monoxide (CO%): Carbon monoxide is an intermediate combustion product and is formed mainly due to incomplete combustion of fuel. If combustion is complete, CO is converted to CO_2. If the combustion is incomplete due to shortage of air or due to low gas temperature, CO will be formed. Usually high diesel CO emissions formed with fuel-rich mixtures, but as diesel combustion is occurred with lean mixture and has an abundant amount of air, CO from diesel combustion is low.CO emission from biodiesel was low when compared with diesel, this is due to higher oxygen content of biodiesel. This Carbon monoxide (CO) is plotted for diesel and biodiesel fuel blended with nano additives as shown in Figure 4.4 while the output results were recorded in Table 4.6 from CT 110 test stand diesel engine.

Table 4.6. CO% emission data recorded from CT 110 test stand diesel engine

Exhaust Emission for CO (%)					
Engine Speed(rpm)	Fuel Sample				
	B0	B20	B20+25ppm	B20+50ppm	B20+100ppm
3400	0.097	0.092	0.091	0.093	0.090
3200	0.089	0.081	0.081	0.082	0.079
3000	0.076	0.069	0.068	0.067	0.067
2800	0.069	0.063	0.064	0.063	0.061
2600	0.063	0.061	0.061	0.060	0.055
2400	0.064	0.064	0.064	0.063	0.059
2200	0.075	0.069	0.068	0.062	0.060

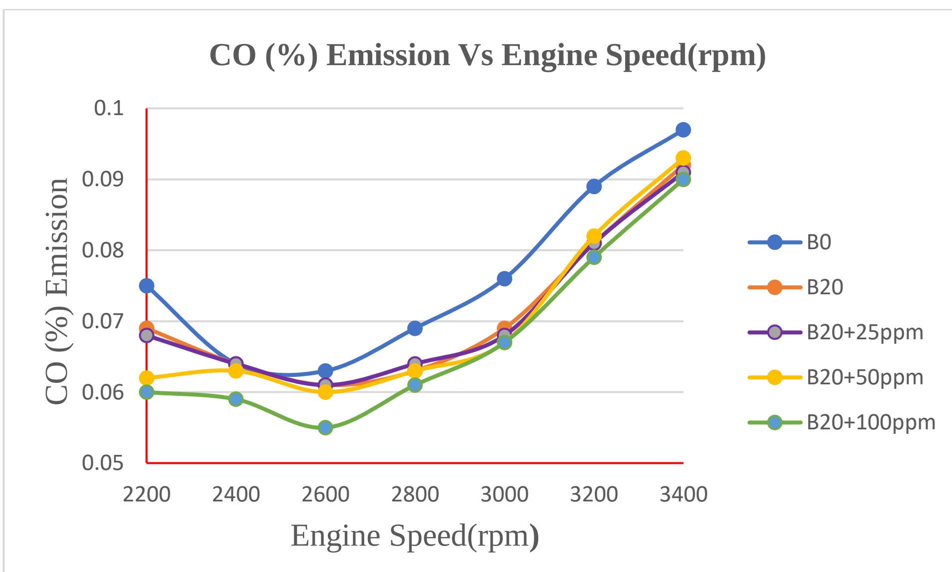


Figure 4.4.Variation of Carbon monoxide (%) Emission with Engine speed at full load

From above Figure 4.4 the graph shows, at lowest engine speed (2200 rpm) the emission of carbon monoxide was high but as engine speed increases it decreased. At engine speed reaches 2800 rpm speed it begins increases and the highest percentage of CO emission was occurred at highest engine speed (3400 rpm). The lowest percentage of carbon monoxide was obtained in B20+100ppm, B20+50ppm and B20+25ppm respectively. this was due to the addition of $NiZnFe_2O_4$ nanoparticles to diesel-biodiesel blends. Therefore, the addition of $NiZnFe_2O_4$ nanoparticles in diesel-biodiesel blends lead to better combustion and reduced CO emission obtained with blend fuel B20+100ppm $NiZnFe_2O_4$.

2.Carbon dioxide (CO_2%): When there is a sufficient air supply, combustion will be complete, thereby carbon dioxide (CO_2%) will be produced since biodiesel has enhanced oxygen content CO was simply converted to carbon dioxide (CO_2%). This carbon dioxide is plotted for diesel and biodiesel fuel blended with nano additives as shown in Figure 4.5 while the output results were recorded in Table 4.7 from CT 110 test stand diesel engine.

Table 4.7. CO_2% emission data recorded from CT 110 test stand diesel engine

Exhaust Emission for CO_2 (%)					
Engine Speed(rpm)	Fuel Sample				
	B0	B20	B20+25ppm	B20+50ppm	B20+100ppm
3400	2.85	2.8	2.8	2.79	2.78
3200	2.7	2.68	2.7	2.69	2.67
3000	2.66	2.63	2.62	2.63	2.63
2800	2.49	2.43	2.48	2.43	2.41
2600	2.42	2.39	2.41	2.41	2.39
2400	2.18	2.15	2.14	2.14	2.13
2200	2.23	2.21	2.21	2.2	2.19

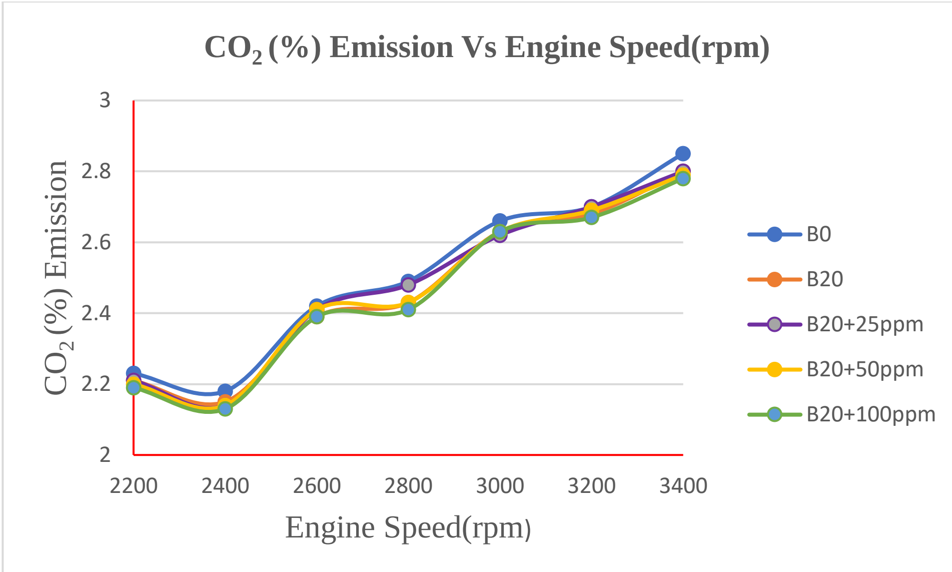


Figure 4.5.Variation of Carbon dioxide (%) Emission with Engine speed at full load

From above Figure 4.5 it is observed that emission of carbon dioxide of diesel fuel is higher than that of all biodiesel blends. This is due to fact that biodiesel has lower elemental carbon to hydrogen ratio than diesel fuel. The minimum percentage of CO_2 emission for all fuel samples were found at engine speed of 2400rpm. At this speed the lowest percentage of CO_2 for B0, B20, B20+25ppm, B20+50ppm and B20+100ppm were 2.18 %,2.15%, 2.14%, 2.14% and 2.13% respectively. From 2600rpm as engine speed increases the percentage of CO_2 emission was increased. The addition of $NiZnFe_2O_4$ nanoparticles to diesel-biodiesel blends was decreased little percentage of CO_2 emission and the reduction CO_2 emission by 2.13% obtained with diesel-biodiesel blend fuel B20+100ppm $NiZnFe_2O_4$.

3. Hydrocarbon (HC%): The formation of the hydrocarbon emissions primarily occurs in the combustion chamber because of the incomplete combustion. It might be led by inappropriate air–fuel mixture, flame cooling and being of crevice volumes. Besides that, the fuel structure, engine construction, and operating conditions are influential factors in the generating for the hydrocarbon emissions (Verma P. et al.,2016).The variation of hydrocarbon emission with respect to engine speed was clearly indicated in Figure.4.6 and the HC analysis data was recorded from the CT test stand diesel engine in Table 4.8 below.

Table 4.8. HC% emission data recorded from CT 110 test stand diesel engine

Exhaust Emission for HC (%)					
Engine Speed(rpm)	Fuel Sample				
	B0	B20	B20+25ppm	B20+50ppm	B20+100ppm
3400	17	17	17	16	16
3200	15	15	15	15	14
3000	14	15	14	14	14
2800	13	14	14	13	13
2600	13	13	13	13	12
2400	13	14	14	14	13
2200	14	15	14	14	13

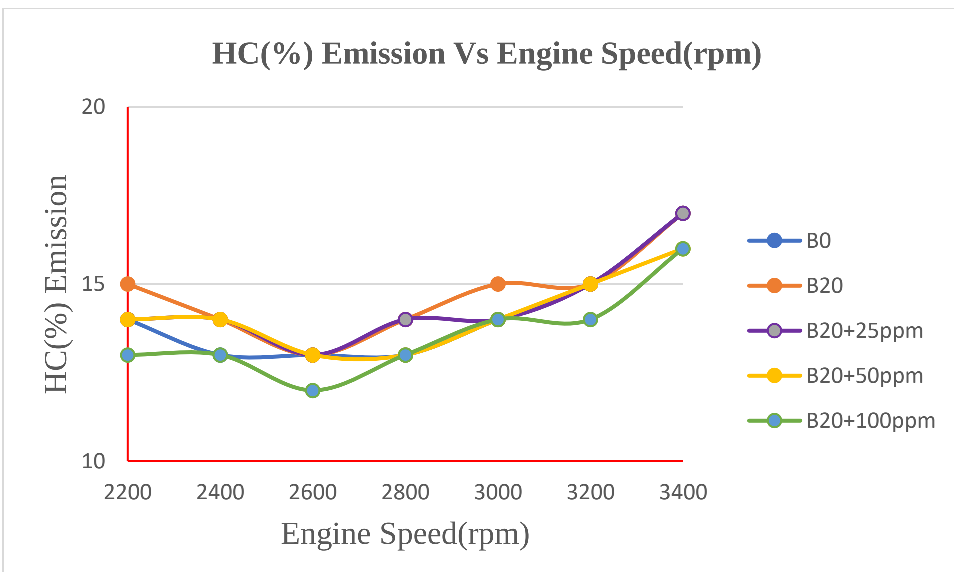


Figure 4.6.Variation of Hydrocarbon (%) Emission with Engine speed at full load

From above Figure 4.6 the graph shows the percentage of hydrocarbon emission was nearly similar for all diesel-biodiesel blends and diesel fuels but with addition of +100ppm to blend decreased little percentage of hydrocarbon emission. At lowest engine speed the HC emission increased but as engine speed increases the HC emission slightly decreased and starts increasing. From the above graph, B20+100ppm and B20+50ppm fuel blends had less HC emission than others as compared respectively, but B20+100ppm had the highest reduction of HC emission compared to all other fuel samples.

4. Oxygen (O_2%): The variation of oxygen emissions for all tested fuel samples with respect to the different engine speeds was illustrated in Figure 4.7 and the oxygen (O_2) analysis data was recorded from the CT test stand diesel engine in Table 4.9. Figure 4.7 was analyzed elaborately, the percentage of oxygen (O_2) emission for the fuel blended of biodiesel was higher than that of pure diesel fuel. The reason is biodiesel contain more oxygen. The maximum percentage of O_2 emission for all fuel samples were found at engine speed of 2200 rpm from B20+100ppm. At this speed the maximum percentage of O_2 for B0, B20, B20+25ppm, B20+50ppm and B20+100ppm were 17.03 %,17.52%, 17.63%, 17.65% and 17.73% respectively. From the graph it can be conclude that as engine speed increases the percentage of O_2 emission was decreased. The addition of $NiZnFe_2O_4$ nanoparticles to diesel-biodiesel blends increased percentage of O_2 emission and the maximum O_2 emission by 17.73% obtained with diesel-biodiesel blend fuel B20+100ppm $NiZnFe_2O_4$.

Table 4.9. Oxygen (O_2%) emission data recorded from CT 110 test stand diesel engine

Exhaust Emission for O_2 (%)					
Engine Speed(rpm)	Fuel Sample				
	B0	B20	B20+25ppm	B20+50ppm	B20+100ppm
3400	16.47	16.76	16.86	16.98	16.98
3200	16.68	16.89	17.12	17.15	17.23
3000	16.76	17.14	17.3	17.32	17.34
2800	16.96	17.37	17.39	17.37	17.44
2600	17.03	17.52	17.63	17.65	17.73
2400	17.28	17.38	17.51	17.59	17.62
2200	17.30	17.41	17.61	17.62	17.71

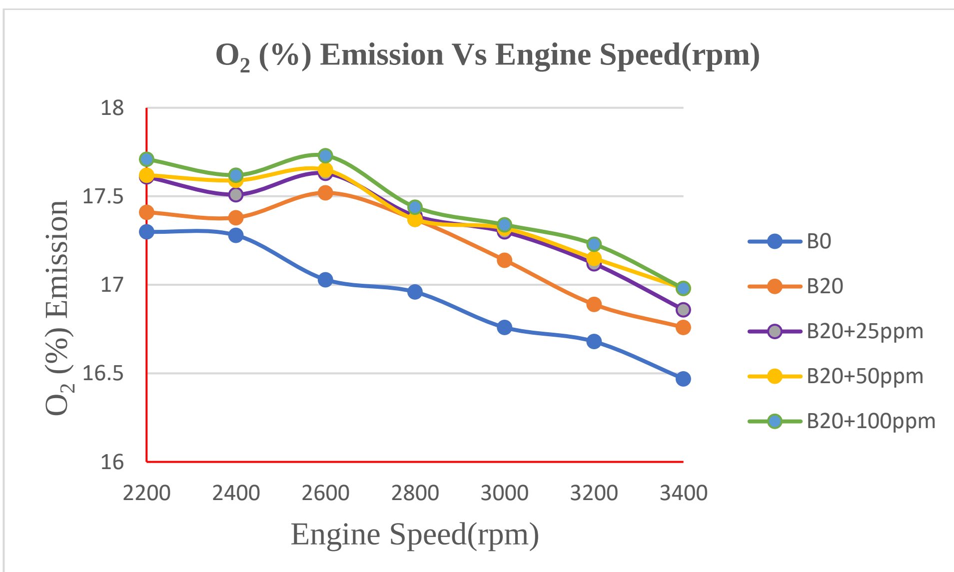


Figure 4.7.Variation of Oxygen (O_2%) Emission with Engine speed at full load

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Summary of the work

The cotton seed oil was obtained from Addis Modjo Edible Oil Share Company. Transesterification process was performed at Chemistry department laboratory of Adama Science and Technology University, Adama, Ethiopia. Transesterification is a process of reaction vegetable oil or animal fats with alcohol(methanol) and KOH to make esterification (ester and glycerol). The aim of this method is to reducing the FFAs found in cotton seed biodiesel and the result obtained were the best for this study. This reaction of cotton seed biodiesel affected by water, reaction temperature, catalyst concentration, molar ratio, reaction time and mixing intensity.

Characterization is the process of determining physiochemical properties of petroleum products and non-petroleum products like biodiesel and diesel-biodiesel blends. The properties of fuel characterized in this study were density, kinematic viscosity, cloud point, calorific value and total acidity. The other significant in this work was addition of nanoparticles on diesel-biodiesel blended (B20+25ppm, B20+50ppm and B20+100ppm) had improved engine performance (brake power, brake torque and brake specific fuel consumption) and exhaust emissions (CO, CO2, HC and O_2).

5.2 Conclusion

This thesis work investigated the production of biodiesel from Cotton seed oil, blending diesel-biodiesel with nickel zinc iron oxide nanoparticles, characterization, engine performance test, and exhaust emission tests were done on single cylinder four stroke CT 110 Test Stand Diesel Engine. The conclusions of this experimental investigation can be summarized as follows:

- Biodiesel was prepared from cotton seed oil by transesterification process. The biodiesel from 1 liter of cotton seed oil was 850 ml and 350 ml made glycerol.

- Biodiesel produced from cotton seed oil was mixed with pure diesel as B20, this diesel-biodiesel blend was completely miscible with nanoparticles in dosing level of (+25ppm, +50ppm and +100ppm) $NiZnFe_2O_4$
- Kinematics viscosity of cotton seed biodiesel are higher than those of diesel fuel and viscosity of diesel-biodiesel blends (B20, B20+25ppm, B20+50ppm and B20+100ppm) were nearly to pure diesel fuel
- Cloud point of cotton seed biodiesel and diesel-biodiesel blends are higher than those of pure diesel fuel and addition of $NiZnFe_2O_4$ nanoparticles was increased the cloud point.
- Depending **o**n the characterization the properties of biodiesel produced and diesel-biodiesel blends fuels found with the range or obeying ASTM standards and Europe standard (EN 14214).
- Brake power and brake torque produced by B20 were slightly lower than that of neat diesel fuel. Indeed**,** addition of $NiZnFe_2O_4$ nanoparticles was increased the brake power and brake torque**.** B20+100ppm had higher brake power and brake torque than other diesel-biodiesel blends and neat diesel fuel. Brake power and brake torque produced by B20+50ppm were 4.98 kW and 14.38 Nm respectively**.**
- Brake specific fuel consumption of B20 higher than that of neat diesel fuel, this may be due to the fact that B20 had lower heating value. However, addition of $NiZnFe_2O_4$ nanoparticles was decreased the value of brake specific fuel consumption.
- The diesel-biodiesel blends (B20, B20+25ppm, B20+50ppm and B20+100ppm) were produced lower percentage of exhaust emissions (CO, CO_2 and HC) but produced higher O_2 emission than that of pure diesel fuel. This may be due to biodiesel was content of more oxygenated, had sufficient oxygen and less carbon molecules.
- Depending on engine performance and exhaust emissions tests it can concluded that the results of diesel-biodiesel fuel blends with addition of $NiZnFe_2O_4$ nanoparticles were related to conventional petro diesel fuel.
- Generally, from this thesis work we concluded that from all tested diesel-biodiesel fuel blends, diesel-biodiesel blends with addition of $NiZnFe_2O_4$ nanoparticles (especially B20+50ppm and B20+100ppm) can be used safely without any modification in engine.

5.3 Recommendation

In this work the characterization was only carried out for viscosity, density, cloud point, calorific value and total acidity of biodiesel and its blended fuel with $NiZnFe_2O_4$ nanoparticles. For better comparison of biodiesel with conventional diesel fuel, characterization of all properties of fuel is recommended. The engine performance and exhaust emissions carried out only for engine brake power, engine brake torque, brake specific fuel consumption and CO, CO_2, HC and O_2. Also, its recommended that testing other engine performance and exhaust emission parameters.

During biodiesel production glycerol was obtained as by product which is very valuable product. So, it is recommended to find the ways to refine the crude glycerol obtained and use for other purpose like cosmetics, pharmaceuticals etc. To save fossil fuels and reduce environmental pollution it is recommended to use diesel-biodiesel blends with nanoparticles and the government has to encourage using the biodiesel blend fuel. Also, it's recommended that ASTU has to create linkage with industry on the mass production of biodiesel and to aware using the biodiesel blend fuel, to save fossil fuels.

For future research work on alternative fuels Department of Mechanical and Vehicle systems of ASTU must have to establish the engine testing workshop.

5.4 Future work

This experimental investigation works the fuel samples tested were B20, B20+25ppm, B20+50ppm and B20+100ppm so to understand the overall behavior of cotton seed biodiesel and effects of nanoparticles so that the work be blending diesel-biodiesel with different proportions and dosing level of nanoparticles. Also, the effect of nano additives on cotton seed oil biodiesel by varying the engine parameters like compression ratio. The other most important future work could be validating result of this blended fuel by using software like neural networks.

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APPENDICES

APPENDIX A
Components of CT 110 Test Stand Diesel Engine

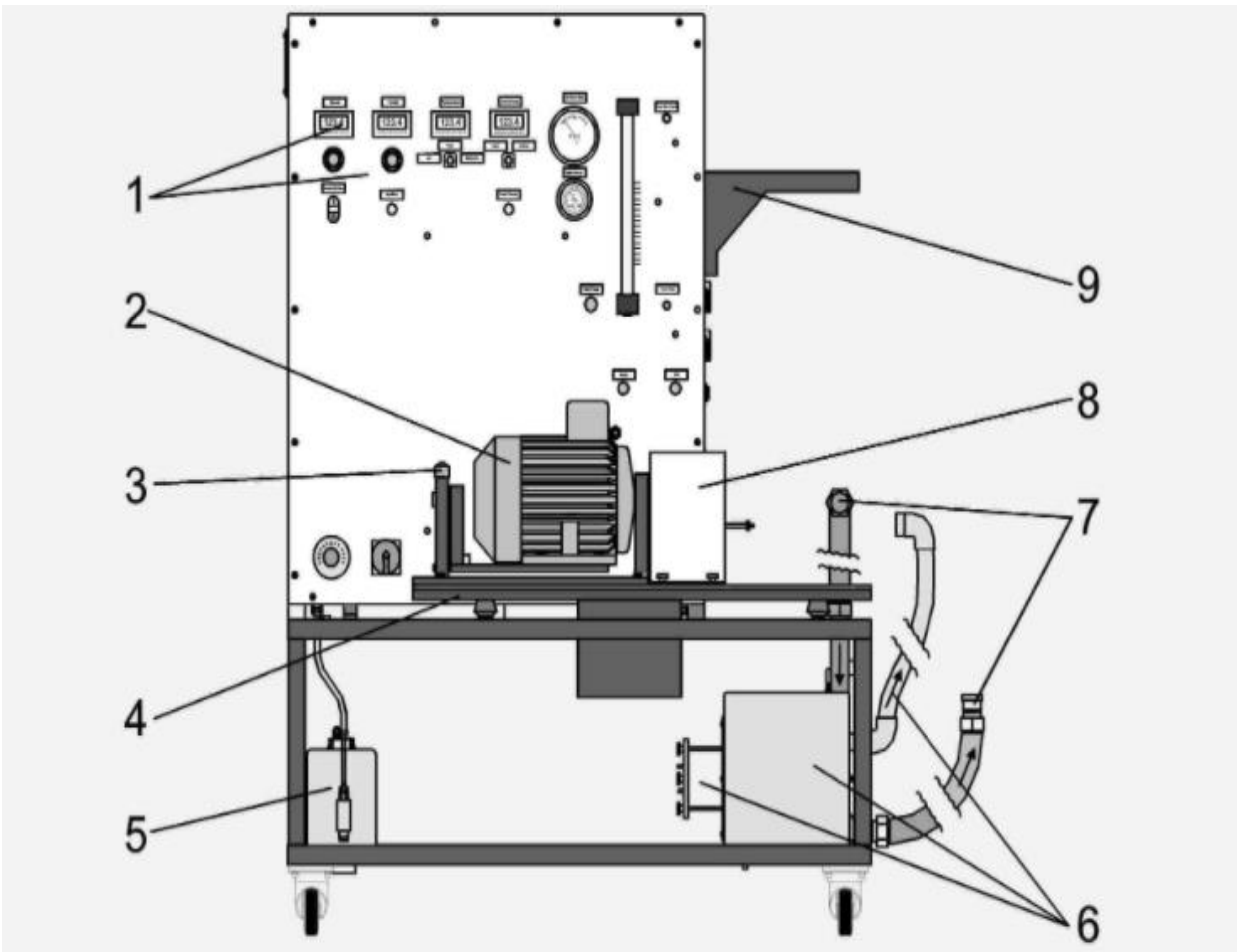

Figure A-1 Components of CT 110 Test Stand Diesel Engine

1. display and control panel
2. asynchronous motor
3. force sensor (torque)
4. base plate
5. fuel tank with pump
6. quietening vessel with air filter and air hose
7. Exhaust gas connection
8. coupling cover
9. shelf, e.g. for CT 100.13

APPENDIX B
Characterization Results

Document number: OF/EPSE/QAS/110

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ETHIOPIAN PETROLEUM SUPPLY ENTERPRISE

CERTIFICATE OF TEST REPORT

ITLE:

sue No.: 2 | Date of issue: July 17, 2019 | Approved by: Tadesse H/Mariam

repared by: QM

Sample Originator: ADAMA UNIVERSITY (ASTU)
Sample Type: BIO DIESEL
Sample Number: 03
Lab. Number: 2019-ADO - EXT-7
Sample Submitted By: CUSTOMER
Test date: 18/03/2020
Customer Address: - ADAMA

Request No: 7/2.1.3/Hm80/8897/12
Analytical Method: ASTM /IP/ISO.
Analytical Result: Interpreted with Stds.
Report No: QA/0009/2020
Date Submitted: 13/03/2020
Issued Date: 20/03/2020
Telephone. +251 988 63 13 77

	Property	Test method ASTM	BD Limits	Test results		
				B20	B40	B100
1.	Density@15°C, g/mL	D4052	Report	0.8459	0.8456	0.8886
	Density@20°C, g/mL	D4052	Report	0.8424	0.8421	0.8851
2.	Calorific value, calc, BTU/LB	Calculated		19,556.9	19,559.6	19,172.6
3.	Cloud point, ^{0}C	D 2500		+1	+12	+10
4.	Kinematic viscosity @ 40 ^{0}c	D 445		3.1871	3.1725	5.2829
5.	Total acidity, mg KOH/g	D974		0.3667	0.340	0.890

Liability: - Ethiopian Petroleum supply Enterprise, its Laboratory, its Servants or agents Shall not be held liable for any damages, loss, claims or expenses direct or indirect howsoever caused, arising in connection with the laboratory test carried out on BIODIESEL sample submitted to it for analysis whether in tort or in contract due to any act, omission or error of whatever nature, whether or not negligence and howsoever caused. Furthermore all expenses and implied warranties are specifically disclaimed. This test report shall not be reproduced or given to a third party without written approval of the Petroleum Quality Assurance Service.

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PLEASE MAKE SURE THAT THIS IS THE CORRECT ISSUE BEFORE USE

Figure B-1 Characterization results

APPENDIX C

ዲላ ዩኒቨርሲቲ
ኢንጂኔሪንግና ቴክኖሎጂ ኮሌጅ
ምር/ቴክ/ሽግ/ም/ዳ/ጽ/ቤት

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ቁጥር ኢ/ቴ/ኮ/ቴ/ሽ/ም/ዳ/23/13

ቀን፡10/01/2013 ዓ.ም

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ጉዳዩ፡- የባዮ ዲዝል ቤተሙከራ መስራትን ይመለከታል

ከላይ በርዕሱ ለመጥቀስ እነደተሞከረው ከዚህ በፊት በተጻፈልን የድጋፍ ደብባቤ መሰረት የሜካኒካል ሲስተም ኤንድ ሞቶር ቬሂክል ኢንጅነሪንግ የሁለተኛ ዲግሪ ተማሪ የሆነው ተማሪ ነጋሳ ተስፋየ የባዮ ዲዝል ቴስት በሜካኒካልና አውቶሞቲብ ኢንጅነሪንግ ቤተ ሙከራ በCT100.32 Diesel Engine ላይ መስራቱን እንገልጻለን፡፡

ከሰልምታ ጋር!!!

ዘውዴ አለማየሁ ሙላት
Zewdie Alemayehu Mulat
የኢንጅነሪንግና ቴክ/ኮ/ምርምርና ቴክ/ሽግግር ም/ዳይሬክተር
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መልሱን ሲጽፉልን የእኛን ቁጥር ይጥቀሱ
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