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BIODIESEL FOR INTERNAL COMBUSTION ENGINE

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M.TECH.
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BIODIESEL FOR INTERNAL COMBUSTION ENGINE

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(M.TECH.)

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بســــــــــــم الله الرحمن الرحيم

هُوَ الَّذِي جَعَلَ الشَّمْسَ ضِيَاءً وَالْقَمَرَ نُورًا
وَقَدَّرَهُ مَنَازِلَ لِتَعْلَمُوا عَدَدَ السِّنِينَ
وَالْحِسَابَ ۚ مَا خَلَقَ اللَّهُ ذَٰلِكَ إِلَّا بِالْحَقِّ ۚ
يُفَصِّلُ الْآيَتِ لِقَوْمٍ يَعْلَمُونَ

صدق الله العلي العظيم

سورة يونس الاية 5

DISCLAIMER

I confirm that the work submitted in this thesis is my own work and has not been submitted to another organization or for any other degree.

Mohammed Hussein Abdzaid

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Date: / /2021

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SUPERVISORS CERTIFICATION

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ABSTRACT

This study compares the compression ignition engine performance and exhaust emissions a CI engine using biodiesel fuel and its blends as the working fuel instead of diesel fuel. At the beginning, the study describes the treatment of the high percentage of free fatty acids in vegetable oil by acid-catalyzed esterification. after treatment of vegetable oil. The transesterification is carried out between vegetable oil and methanol at a molar ratio of 6:1. From this process, biodiesel and glycerin are produced. Biodiesel is washed and dried then after that, the study deals with calculating the physical and chemical properties (density, flash point viscosity and cetane number) of the fuel produced and comparing them with Standard values for biodiesel EN 14214.

This work investigates engine performance and exhaust emission of diesel, biodiesel and its blends the (B10, B20, B50 and, B70).

The engine's performance parameters were brake power, brake specific fuel combustion, brake thermal efficiency, and volumetric efficiency at various engine speeds (1000, 1500, 2000, 2250, and 2500 RPM) and variable loads (0, 25, 50, 75, and 100%), as well as emissions (CO, CO_2, HC and NOx).

The break thermal efficiency of B10, B20, B50, B70, and biodiesel fuel blends decreased by values of 0.76%, 1.53%, 2.56%, 3% and 3.66%, respectively, compared to fossil diesel fuels. The specific fuel consumption increased by 0.03 kg/kW-h, 0.05 kg/kW-h, 0.08 kg/kW-h, 0.12 kg/kW-h,, and 0.154 kg/kW-h, respectively, compared to fossil diesel fuels. Volumetric efficiency appears negative behavior with the increase in the engine load and alternative fuel blending or dedicated where it decreases. The brake power decreases with an increase in the percentage of biodiesel in fuel mixtures compared to fossil diesel fuels There is a significant decrease of exhaust gas emissions in (CO and HC) with a using biodiesel fuel and an increase in all biodiesel blends as compared to the diesel fuel and (CO2 and NOx) increase compare to diesel fuel. Maximum reduction in CO emissions was found at B100 by (84.1%), in HC emissions were found at B100 by (17%). The exhaust gas temperature increases with increase of the engine load. For the same engine load and speed, it is found that exhaust gas temperatures for diesel fuel be higher at all the engine loads compared to biodesel fuel. The maximum exhaust gas temperature reported was 227C° for B10 fuel for engine speed equals to 2500.

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NOMENCLATURE

Symbol	Definition
ASTM	American Society for Testing and Materials
B10	(10% biodiesel and 90% diesel)
B100	Pure biodiesel
B20	(20% biodiesel and 80% diesel)
B30	(30% biodiesel and 70% diesel)
B40	(40% biodiesel and 60% diesel)
B5	(5% biodiesel and 95% diesel)
B50	(50% biodiesel and 50% diesel)
B60	(60% biodiesel and 40% diesel)
B70	(70% biodiesel and 30% diesel)
B75	(75% biodiesel and 25% diesel)
B80	(80% biodiesel and 20% diesel)
B90	(90% biodiesel and 10% diesel)
BP	Breake Power
BSFC	Brake Specific Fuel Consumption
BTE	Brake Thermal Efficiency
CO	Carbon Monoxide
CO_2	Carbon Dioxide
FFA	Free fatty acid
H_2SO_4	Sulfuric acid
HC	Hydrocarbon
IEC	International Electrotechnical commission
LHR	Low Heat Rejection
$\dot{m}_f$	fuel consumption

NaOH	sodium hydroxide
NOx	Nitrogen oxides
STD	Standard transmission drive
VDAS	Versatile Data Acquisition System
η_v	Volumetric Efficiency
η_t	Brake thermal Efficiency

CHAPTER ONE

INTRODUCTION

1.1 Background

Global warming is one of the most significant environmental issues confronting our society today. The increase in atmospheric greenhouse gases caused by human activity has been the principal cause of climate change since the beginning of the industrial epoch. Gaseous, solid, and liquid pollution are all produced by burning fuels. When operating internal combustion engines (ICE), there are only a few types of pollutants to consider: nitrogen oxides (NO_X), carbon monoxide (CO), hydrocarbons (HC), and carbon dioxide (CO_2) as shown in table (1-1). In addition to these basic pollutants, secondary contaminants such as acid rain, photochemical smog, and tropospheric ozone are produced by atmospheric interactions. Many of these toxins are hazardous to human health and the environment. As a result, many countries have passed strict environmental regulations that must be followed by all automobile manufacturers.[1]

Table 1-1 European emission standards for passenger cars, g/km Transport & Environment, accessed on May 7, 2018 [1]

Tier	Date	CO	NO_X	$HC+NO_X$	PM	PN
Diesel						
Euro 4	January 2005	0.50	0.25	0.30	0.025	-
Euro 5a	September 2009	0.50	0.180	0.230	0.005	-
Euro 5b	September 2011	0.50	0.180	0.230	0.005	6×10^{11}
Euro 6	September 2014	0.50	0.080	0.170	0.005	6×10^{11}

The most popular replacement fuel for traditional diesel engines is biodiesel, which is a general word for fatty acid alkyl esters. Because of its cost benefits, fatty acid methyl ester is increasingly commercially developed.

Biodiesel provides for more than 80% of the biofuel demand in Europe[2]. Biodiesel do not includes sulphur, aromatic hydrocarbons, metals, or crude oil because it is manufactured from vegetable oil. leftovers Sulphur deficiency results in less acid rain due to sulphate emissions, which release sulphuric acid into the environment.

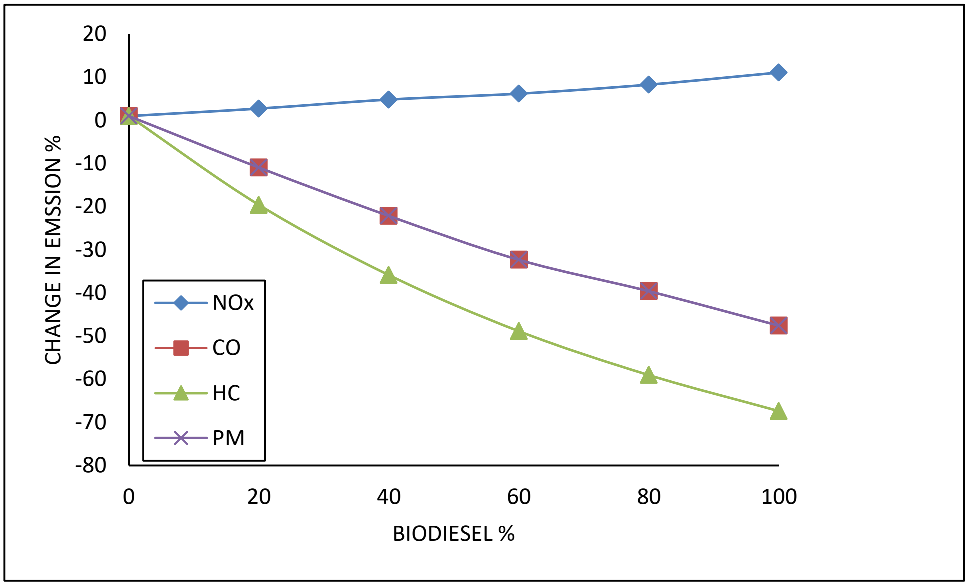


Figure 1-1 Relationship between the percentage of biodiesel and percentage change in emissions[9]

1.2 Biodiesel as an alternative fuel

The increase consumption of natural energy sources as shown in figures (1-2), (1-3) and (1-5), so the word So, researchers tried to reach the ideal alternative to diesel fuel .Biodiesel (esters generated from vegetable oils) has been revealed to be a very promising fuel in recent decades. B20, which is made up of 20% biodiesel and 80% petroleum diesel, is the most prevalent mixture. The following advantages are at the heart of biodiesel's widespread use.[3]

- Biodiesel is a non-petroleum-based, potentially renewable fuel.
- Combustion of biodiesel emits less greenhouse gases.
- Biodiesel is less volatile and biodegradable than conventional diesel.
- CO, HC, air toxics, and other pollutants can be reduced by using biodiesel as shown in figure (1-1).
- need not modifications for the traditional CI engine to burn biodies.

Biodiesel also has some negative attributes [3]

- Lower heating value, higher viscosity
- Storage stability is compromised, and material compatibility is a problem.
- NOx emissions are slightly higher.

Higher NOx emissions from biodiesel-fueled engines, among the above characteristics of biodiesel, are a key worry due to tougher laws, and thus serve as the key impetus for this research.

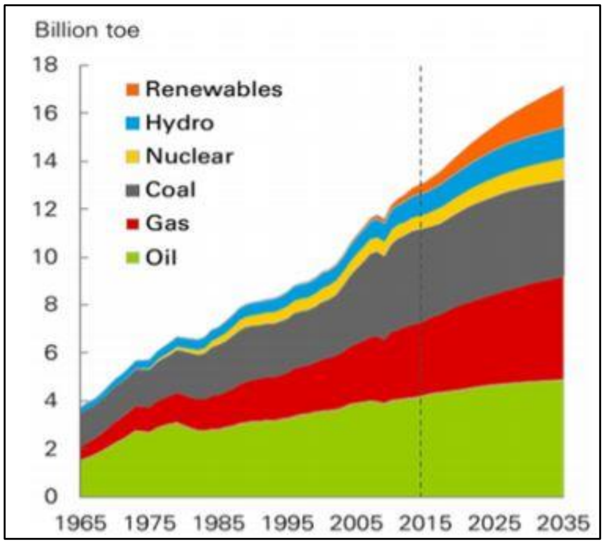


Figure 1-2 Energy consumption growth forecast for 2015–2035[56]

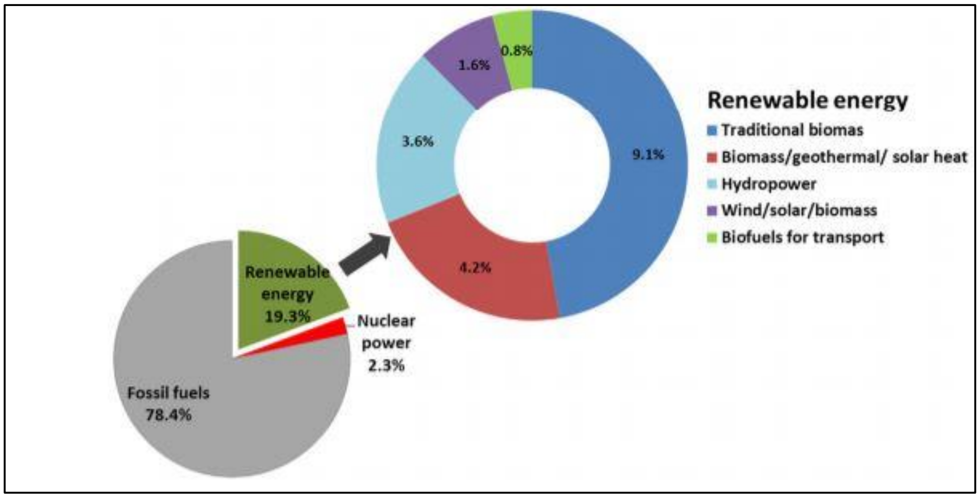


Figure 1-3 World energy consumption in 2015. [57]

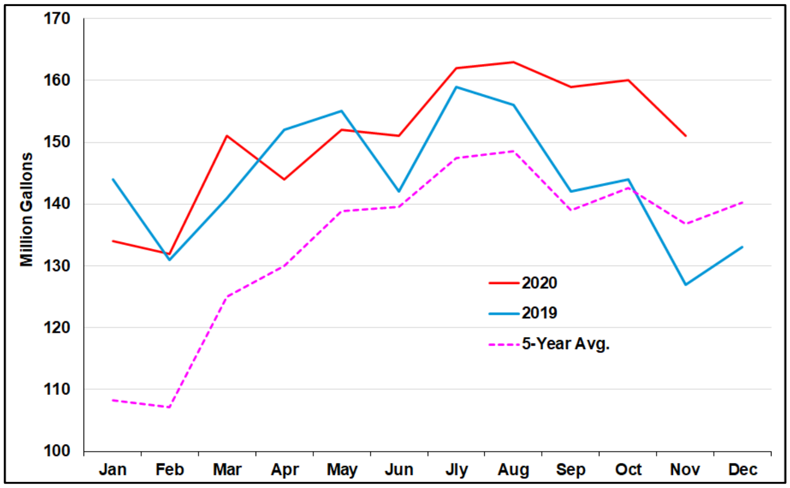


Figure 1-4 Biodiesel Production Profits in 2020 [58]

1.3 Biodiesel Standards

To meet the output requirements of a diesel engine, biodiesel must adhere to tight regulatory guidelines. The American Society for Testing and Materials (ASTM) International produced ASTM D6751 to describe several test methodologies to be utilized in calculating specific properties for biodiesel blends. To sell their biodiesel industrially, biodiesel producers must meet specific specifications.

Table 1-2 Summary of 100% biodiesel testing standard ASTM D 6751. (ASTM, 2008)

Property	Test method	Grade S15 limits	Grade S500 limits	Units
Calclum and magneslum combined	EN 14536	5 max	5 max	Ppm (µg/g)
Flash point	D 93	93 min	93 min	ºC
Acohol control				
On of the following must be met:				
1. Methanol content	EN 14110	0.2 max	0.2 max	Mass %
2. Flash point	D 93	130 min	130 min	ºC
Water and sediment	D 2709	0.050 max	0.050 max	% volume
Kenematic viscosity, 40 ºC	D 445	1.9-6.0	1.9-6.0^B	mm^2/s
Sulfated ash	D 874	0.020 max	0.020 max	% mass
sulfur	D 5453	0.0015 max (15)	0.0015 max (15)	% mass (ppm)
Copper strip corrosion	D130	No. 3 max	No. 3 max	
Cetane number	D 613	47 min	47 min	
Could point	D 2500	Report	Report	ºC
Carbon residue	D 4530	0.050 max	0.050 max	% mass
Acid number	D 664	0.50 max	0.50 max	mg KOH/g
Cold soak filterability	Annex A1	360max	360 max	seconds
Free glycerin	D 6584	0.020 max	0.020 max	% mass
Total glycerin	D 6584	0.240 max	0.240 max	% mass
Phosphorus content	D 4951	0.001 max	0.001 max	% mass
Distillation temperature	D 1160	360 max	360 max	ºC
Soduim potassuim, combained	EN 14538	5 max	5 max	ppm (µg/g)
Oxidation staiblity	EN 14112	3 min	3 min	hours

1.4 Problem statement

Many health problems, such as trouble breathing, asthma, lung and heart disease, and cancer, are linked to air pollution. This study provides a comprehensive overview of biodiesel combustion's role in reducing pollutant emissions caused by the burning of fossil fuels, hence reducing negative health and environmental consequences. Also, fossil fuels are a nonrenewable energy source. Natural formation takes thousands of years, and they cannot be replaced as quickly as possible since they are being consumed. The price of petroleum has risen dramatically as a result of rising demand and limited availability. Even though oil prices are far lower (0.375 USD) today than they were in 2006 (1.4 USD), the volatile oil price increase will leap as far as it wants, and we will almost certainly see another oil spike that will surely overthrow the highest price from the previous 2021 oil rise.[4]

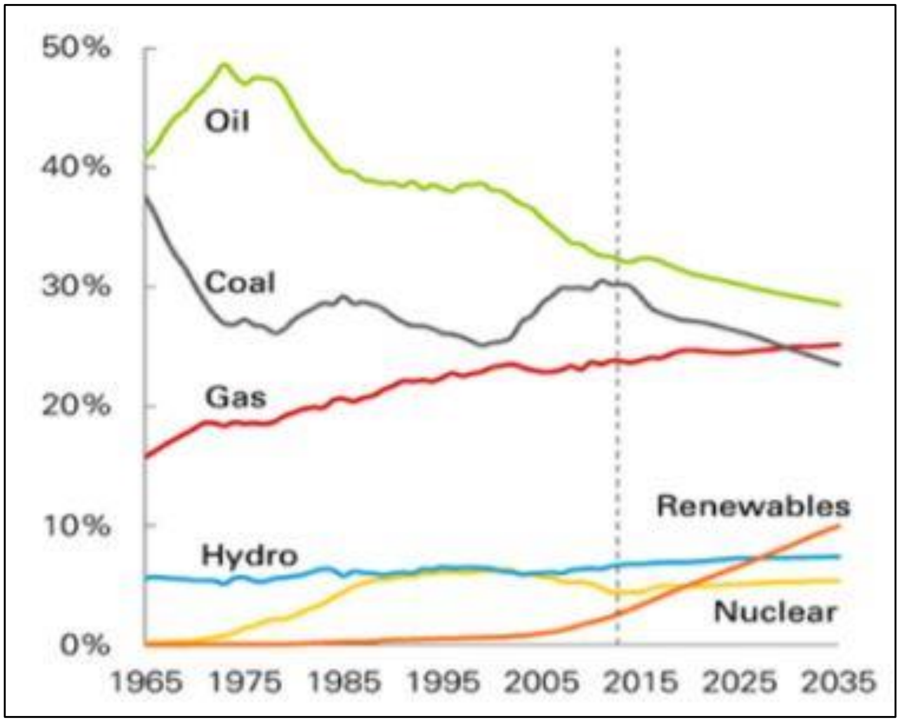


Figure 1-5 Shares of primary energy forecast for 2015–2035. [56]

1.5 Rationale and Significance

Due to the depletion of petroleum resources, an ambitious search for renewable energy sources has begun, and Biopetrol is one of the most promising solutions now accessible as shown in figure (1-4). Biopetrol can be extracted endlessly using renewable resources, hence world energy demand will not be reduced. Biodiesel research has received a lot of attention, and it has been established and used on the road for diesel-powered vehicles, but biopetrol has not. This research could lead to the commercialization of biopetrol processing. Biofuel was often blamed for the rise in food prices. The cost of corn grain has grown by double as a result of bioethanol manufacturing in the United States of America. In the 2008 global food scandal; Global Food Price, 70 percent of the increase in food costs is due to weather, and 30 percent is due to bio-fuels. The greatest solution is to use underutilized crops and non-edible plants. Rubber trees cover more than 100,000 hectares in Malaysia, and its seeds are not consumed or used for any other purpose[5]. Biopetrol is a non-toxic, environmentally friendly liquid fuel. There's rising interest in using vegetable oils to generate biopetrol because it is less polluting and more sustainable than standard petroleum diesel fuel. The most important distinction between biofuels and petroleum feedstocks is the oxygen content. Biofuels contain oxygen levels ranging from 10% to 45%, whereas petroleum has nearly none, giving them chemical characteristics that are distinct from petroleum. Many of them have very low sulfur levels and very low nitrogen levels[6].

1.6 Diesel engine

The injection of oil fuel into air that has been previously compressed by the raising of a piston to a pressure corresponding to a temperature sufficiently high to assure prompt ignition of the fuel is a distinguishing feature of the diesel engine. During the pioneering studies that showed the engine's commercial viability, it was discovered that injecting the fuel with a burst of air was more efficient, and this feature was preserved in all Diesel Engines until the original patents expired. There is currently a class of high-compression oil engines based on the Diesel principle in which oil injection is accomplished mechanically rather than with the aid of an air blast. These engines present a unique set of challenges that differ significantly from those encountered in the design of diesel engines, as detailed below. Furthermore, the usage of one of the most visible members of this class of engine for military purposes precludes any meaningful discussion of these so-called " solid injection " engines. The well-known " surface ignition," " hot bulb," or " hot plate " engines are a distinct class of their own, and have been referred to as " semi-Diesel " engines in the past. They fall outside the preview of this article since the cycles on which they run and the ideas underpinning their design are so dissimilar from those relevant to Diesel Engines show figure (1-6). The characteristics of a real Diesel Engine, in the proper sense of the term, are now regarded to be as follows [7] :-

- Compression sufficient to produce the temperature requisite for spontaneous combustion of the fuel.
- Injection of fuel by a blast of compressed air.
- A maximum cycle pressure (attained during combustion) not greatly exceeding the compression pressure, i.e absence of pronounced explosive effect.

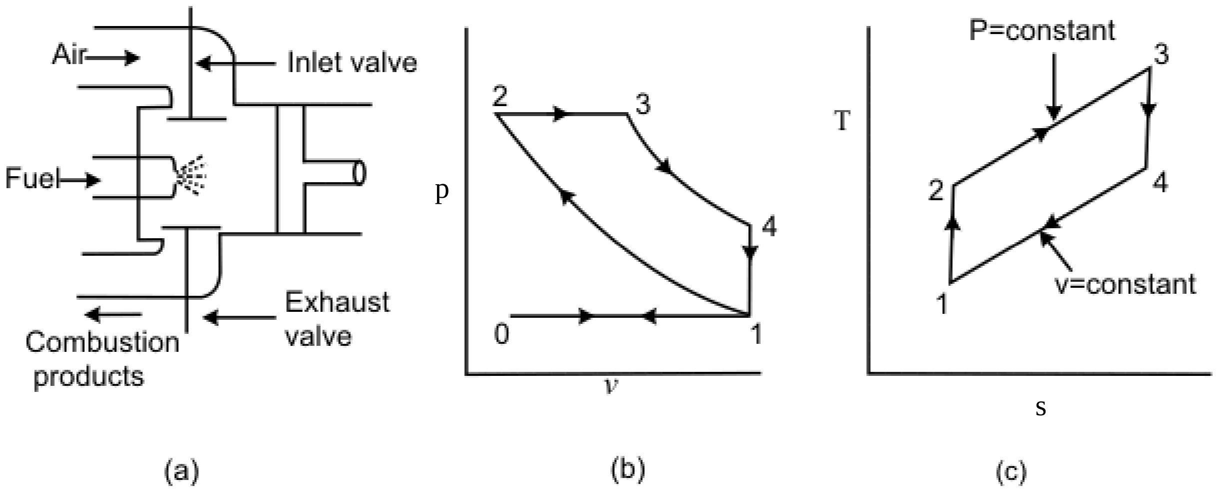


Figure 1-6 Diesel cycle a) combustion chamber b) diesel cycle c) T-S diagram.[7]

1.7 Objectives

The purpose of this research is to investigate the performance and exhaust emissions of two types of fuel and diesel fuel. The specific objectives of the study are as follows: several specific tasks need to be done

- Reducing percentage of free fatty acids in vegetable oil to conduct Biodiesel preparation by transesterification process
- Reducing exhaust emissions of internal combustion engines to preserve the environment, as fossil diesel fuels contain higher emissions.
- Comparing the results of operation of the internal combustion engine fossil diesel fuel with biodiesel fuel

CHAPTER TWO

LITERATURE REVIEW

2.1 Biodiesel for Internal Combustion Engine

Methyl esters are often referred to as biodiesel due to their similarities with diesel in many physical and chemical properties. Biodiesel can be mixed with diesel in any combination and used in internal combustion engines. The main problem with biodiesel its high flash point compared to fossil diesel.[8] Biodiesel helps reduce exhaust emissions compared to fossil diesel fuels [9]

2.2 Acid-Catalyzed Esterification

K. V. Thiruvengadaravi et al. showed the most important factors affecting the reaction in the acid esterification are the alcohol-to-oil molar ratio, the amount of acid catalyst, and the duration of the reaction. In this study, oil was poured into the flask and heated and the percentage of the acid catalyst was 1%. Methanol was added and the reaction was conducted for two hours with molar ratios of alcohol: oil 3:1, 6:1, 9:1, 12:1, and 15:1. The concentration was reduced FFA to 4 mg KOH/g. [10]

J. Zhang et al. used 80 grams of vegetable oil that were added to reaction and heated to the reaction temperature. Then the sulfuric acid and methanol solution was heated and added to the reaction. Stir the mixture at 600 RPM. The reaction was left for an entire night to precipitate, after which the methanol was separated. The reaction time was (20 - 120) minutes The acid value of ZSO with high FFA can be reduced to less than 2 mg KOH/g in only one-step pretreatment of esterification using H_2SO_4 as catalyst. [11]

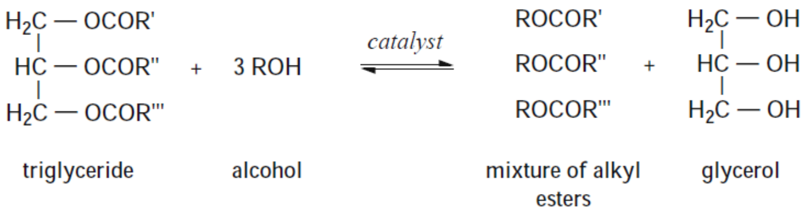
M. Naika et al. The tests conducted proved extremely useful as the pretreatment of high FFA Karanja oil resulted in the reduction of acid value to an extent, which is suitable for alkali-catalyzed transesterification. Then the conventional alkali-catalyzed transesterification of pretreated oil was used in the reaction to compensate for the acidity due to H_2SO_4 and the remaining part acted as transesterification catalyst. Thus, transesterification was very effectively carried out, which resulted in the desired products, biodiesel and glycerol layer.[12]

W. J. Ting et al. conducted a reaction between oil and methanol in the presence of a number of acid catalysts (sulfuric, hydrochloric, nitric, phosphoric, or acetic acid). The reaction took place at a temperature of 50 degrees Celsius under constant stirring. After the reaction, the methanol was removed by evaporating it to 65 °C. The esterification of the feedstock by methanol at optimized conditions (50 8C; feedstock to methanol molar ratio of 1:15; 2.5% sulfuric acid) led to 99% conversion of biodiesel after 12 h. [13]

A. V. Metre et al. performed the esterification using methanol and phosphoric acid as a catalyst with stirring, a temperature control unit, and a condenser. A molar ratio of 6:1 to 12:1 was used, and the molar ratio was from 5% to 9%. The reaction was carried out at a temperature of 50 to 60 °C and the product was heated to 100 ° C to remove the methanol.[14]

2.3 Transesterification

Transesterification is the conversion of one ester-type to another ester type. The main goal of biodiesel is to decrease the viscosity of vegetable oil or animal fat to use it as a new source of energy. The reaction turns the triglyceride acids into diesel to a certain extent methyl ester. In transesterification, alcohol is reacted with fatty acids in vegetable and animal oils to convert them into methyl ester show equation (2-1). [15] Triglycerides are converted to diglycerides that react with the alcohol Methanol or ethanol to monoglycerides. Monoglycerides in turn proceed to the final step to give the methyl esters and glycerol.[16]



........(2.1)

The use of alcohol varies by theme physical state in which it is fed into the reaction. The alcohols used in the reaction were always in a liquid state, recent development showed the possibility and the potential of using them in the supercritical form to transesterification oils and produce biodiesel alcohol used to the transesterification is mostly either ethanol or methanol. Methanol is the most common choice due to the fact that it is cheaper. [17]

In the separation process, the glycerol layer is separated from the biodiesel layer by the difference of densities by a separation funnel. This process occurs naturally when using methanol or ethanol in the presence of a base catalyst, so the glycerol layer is down and the biodiesel up.[15]

Afterward, the biodiesel is washed with water at a temperature of 70 degrees Celsius to get rid of the excess methanol from the reaction and this process is repeated several times until obtaining clean water. Then the biodiesel is dried by heating it to 110 degrees Celsius for a full hour to get rid of the moisture resulting from the washing process.[15]

2.4 Fuel Properties

The kinematic viscosity and density of the fuel affect the engine directly. The researchers conducted a density test with a device stabinger viscometer، and the researcher took the values of the kinematic viscosity, dynamic viscosity and density at a temperature of 40 ºC. Then the research determined the calorific value of biodiesel by LECO AC-350 digital bomb calorimeter[6]. The researchers show the kinematic viscosity of biodiesel was calculated at a temperature 40 ºC and its value was found (3.5-5) mm^2/s. While the researcher found that the density value at a temperature 15 ºC equal to 0.888 g/ml. The biodiesel in this study has very high flash point 156 ºC compare with diesel 72 ºC.[18]

Table 0-1 Standard values for biodiesel EN 14214 [18]

Properties	Standard values for biodiesel EN 14214
Flash point	≥ 120 ºC
Dynamic viscosity	$3.5 - 5$ mm^2/s
Cetane number	> 51
Density	$0.86 - 0.90$ g/ml

2.5 Engine performance

Among the most important characteristics that affect fuel consumption in a diesel engine are viscosity, density, surface tension, and heating value of the fuel. The amount of injected fuel is controlled in the control systems, as increasing fuel density leads to pumping a larger mass of fuel to reach the same volume.[19]

2.5.1 Brake Thermal Efficiency

S. Bari et al. are a measured of the thermal efficiency of fuel combustion. The researchers used Cussons single-cylinder engine testbed model P8160 where he found that the brake thermal efficiency of biodiesel is less than that of diesel, as the highest percentage of biodiesel was 20% while the diesel was 21% and fuel consumption decreased by 10% for biodiesel compare to diesel.[20]

Upendra Rajak et al. showed the brake thermal efficiency of B100% was relatively low as compared to diesel. This is primarily due to a lower calorific value of microalgae spirulina biodiesel from diesel. there was a reduction of 0.63% in the BTE of the engine at B20% as compared to diesel. The result found that BTE for B0%, B20%, B40%, B60, B80% and B100% are 33.51%, 33.3%, 33.18%, 33.0%, 32.5 % and 32.1% respectively at full load condition of engine. The overall reduction in the efficiency of B100% was about 4.2% from diesel.[21]

H. Raheman et al. used a single-cylinder, four-stroke, water-cooled Ricardo E6 engine, the highest value of brake thermal efficiency was 25% when using B20 and B40 was 24% due to an increase in the amount of oxygen at B20, which led to better combustion than fossil diesel. At full load, the average brake thermal efficiency of the B100 is 10.1% less than the brake thermal efficiency of fossil diesel. At lower loads, the brake thermal efficiency of the B100 is much lower than that of fossil diesel.[22]

M. S. Gad et al. used single cylinder, four strokes, air-cooled, direct injection, naturally aspirated, constant compression ratio, diesel engine. B20 and B100 had a slightly lower thermal efficiency at all loads than fossil diesel when the researcher concluded that this decrease is due to a decrease in the calorific value, high viscosity, and high density of biodiesel, where the brake thermal efficiency of the diesel was 28.7%, B20 biodiesel was 27.7% and B100 was 24.7% at full load. [23]

P. Shrivastava et al. investigated the brake thermal efficiency varies with the different loads, as with the increase in the load, the brake thermal efficiency increases in all circumstances. The brake thermal efficiency decreases with the increase in the biodiesel content, due to the fact that the viscosity of biodiesel is higher than that of fossil diesel. Large droplets are formed when biofuels dissolve as a result of viscosity, high evaporation, and high density. This leads to the formation of an irregular mixture of fuel and air. The researcher found the brake thermal efficiency of B20 is 32.9% and for B 10 is 32.5%. The brake thermal efficiency of B10 and B20 is much better than that of B100.[24]

S. Chattopadhyay et al. investigated the brake thermal efficiency inversely proportional to the brake specific fuel consumption as the decrease in brake specific fuel consumption with the engine load leads to an increase in brake thermal efficiency. The researchers found that the values of the brake thermal efficiency of fossil diesel are 23.09%, for B10, 22.8%, and for B20, 22.7%. The lower brake thermal efficiency of biodiesel results from its higher density and higher viscosity compared to fossil diesel.[25]

S. Simsek used a naturally aspirated, air-cooled, single-cylinder, four-stroke, the direct injection diesel engine with a fixed speed of 3000 rpm. It was found that the decrease by thermal efficiency of B10, B20, B30, B50, B75 and B100 is 0.80%, 0.73%, 2.22%, 3.37%, 4.20%, respectively compare to diesel fuel. The decrease in brake thermal efficiency is observed with the increase in the percentage of biodiesel, and this is due to the decrease in the calorific value of biodiesel. Biodiesel helps to burn more than diesel due to the high number of cetane and the proportion of oxygen in it. The higher cetane number reduces the ignition delay period, thus reducing the brake thermal efficiency of the B100 diesel.[26]

D. Sinha et al. used a four-stroke, single-cylinder, air-cooled, and direct injection diesel and found that the brake thermal efficiency of biodiesel is lower for all mixtures than for fossil diesel. This is due to the poor mixing of the fuel with the air, the poor spraying property, and the high viscosity. [27]

2.5.2 Brake Specific Fuel Consumption (BSFC)

S. Bari et al. . investigated the brake specific fuel consumption that denotes the fuel flow rate per unit power. The lower brake-specific fuel consumption the more desirable it is. In diesel engines, it can reach 200 g / kWh. According to the study, brake specific fuel consumption seemed to decrease at full engine load. At medium loads, brake specific fuel consumption was high with respect to biodiesel due to its low calorific value due to the high oxygen content. Therefore, in order to achieve the same brake power, the increased the percentage of brake specific fuel consumption was results of the decrease in the calorific value of biodiesel. Where the minimum value for biodiesel was 440 g/kWh, while for fossil diesel it was 400 g/ kWh. On average, the brake specific fuel consumption of biodiesel was 10% higher than that of fossil diesel.[20]

J. N. Nair et al. showed the brake specific fuel consumption of fossil diesel and B10 was less than the brake specific fuel consumption of B20 and B30 at all loads, with the highest value of brake specific fuel consumption for B30 reaching 1 Kg / kWh. The researcher explained that the reason for the increased brake specific fuel consumption of biodiesel is the lower calorific value compared to fossil diesel, as more energy is consumed to obtain the same energy output. [28]

H. Raheman et al. proved that with the increase in the percentage of biodiesel in the fuel, the fuel consumption increases, and this consumption gradually decreases with the increase in the load for all types of fuel. The reason for this is that the engine needs to consume more fuel to reach the same energy. It was found that the percentage of fuel consumption decrease for B20, B40, B60, B80 and B100 is 4.3%, 18.6%, 19.6%, 31.7% and 41.4%, respectively. The researchers also concluded that higher fuel densities consume more fuel. With B100 its density was 4% higher than that of fossil diesel. The higher density causes fuel to be injected with a larger mass of the same volume. The enthalpy of the biodiesel, B40, B60, and B80 blends was also lower than that of the fossil diesel.[22]

M. S. Gad et al. explained that the fuel consumption of biodiesel and all its mixtures is higher than the fuel consumption of fossil diesel, and the reason for this is due to the lower calorific value of biodiesel compared to that of diesel. The fuel consumption values for diesel, B20 and B100 were 0.28, 0.316, 0.346 kg/kW.hr, respectively at full load. [23]

P. Shrivastava et al. showed the Fuel consumption decreases with increasing load as the engine efficiency increases with increased fuel consumption. In this study, the fuel consumption was higher for the mixture of biodiesel than for fossil diesel. The fuel consumption for Roselle biodiesel B10, B20, and B100 was 5.40%, 6.48%, and 13.42% respectively and for Karanja biodiesel for B10, B20 and B100 was 6.84%, 8.58%, and 16.63%

compared to that of fossil diesel at full load. This decrease is due to the fact that the calorific value of biodiesel is lower than that of fossil diesel.[24]

S. Chattopadhyay et al. the average values of fuel consumption were calculated for B10 and B20, and they were 0.415 and 0.418 kg/kW h^{-1}, respectively, compared to fossil diesel 0.407 kg/kW h^{-1}. Where the researcher noticed that the value of fuel consumption does not change much for B10 and B20 mixtures. The reason for this is the low calorific value, high density, and high viscosity.[25]

S. Simsek found that the fuel consumption values for B10, B20, B30, B50, B75, and B100 are 3.79%, 6.47%, 9.27%, 12.89%, 15.55%, and 19.80% respectively, as the fuel consumption was high compared to fossil diesel, where the researcher explained that High viscosity, low calorific value, and high density have an obvious effect on fuel consumption.[26]

D. Sinha et al. indicated that the consumption of biodiesel was higher than the consumption of fossil diesel for the same resulting power. Where the researcher explained that high density is the main reason for the increase in fuel consumption. [27]

2.5.3 Break power

Ankur Nalgundwar and et. al. brake power of biodiesel less average 4.65% than diesel. Apart from that pure diesel dominated the output brake power at various loads. The viscosity and density plays major roles in atomization process of fuels and can slow down the fuel–air mixing rate, which can result in poor combustion of fuels leading to a lower brake power. Due to higher kinematic viscosity and density jatropha biodiesel blends have about 5.3% lower break power than palm biodiesel. It was observed that there was not any higher reduction in brake power for lower blends of biodiesel than diesel. B20, B30 and B40 showed 3.98%, 7.04% and 2.44% reduction in brake power respectively. This decrease due to higher viscosity, density and lower calorific values.[6]

A.M. Liaquat et. al. showed It can be observed that brake power of the engine increases with increasing engine speed until 2200 rpm and then starts to decrease due to the effect of higher frictional force. The engine brake power for biodiesel blends was found to be lower than obtained for net diesel fuel. The lower brake power for B5 and B15 can be due to their respective lower heating values. The average power reduction compared to diesel fuel over the entire speed range is found as 0.66% for B5% and 2.61% for B10% respectively. [29]

2.5.4 Volumetric efficiency

J. Jayaprabakar et al. showed the volumetric efficiency of an engine indicates how well it can breathe. This feature is influenced by the surrounding environment as well as the engine's operating circumstances. Because of the increased cylinder temperature, the volumetric efficiency of the rice bran methyl ester mixes and algal methyl ester blends is nearer to pure diesel. The cylinder temperature rises and the volumetric efficiency of all fuel types rises when the injection timing is advanced. Due to the lower cylinder temperature, both volumetric and thermal efficiency are reduced when the injection is delayed. The volumetric efficiency decreases as the power output increases.[30]

K. S. Karthi et al. investigated comparing twin blend biodiesels to diesel fuel, there is not much difference. For all biodiesel mixes, the volumetric efficiency at average brake power is constant. At a given average brake power, B10 and B15 have nearly identical volumetric efficiency. At 5 kW, pure diesel has a volumetric efficiency of roughly 85.31 %. B10 has a volumetric efficiency of approximately 84.31 %. At the same power, B20 has a volumetric efficiency of roughly 84.73 percent. As a result, there will be very little variation in volumetric efficiency.[31]

2.6 Exhaust emissions

2.6.1 NO_x Emission

Biodiesel has higher NOx emissions than gasoline and diesel because biodiesel contains more oxygen molecules. According to the **S. Bari et al**., the proportion of nitrogen oxides increases with increasing load. At 2800 rpm, the emissions of nitrogen oxides were found to be 520 ppm for biodiesel, while emissions of nitrogen oxides over the same speed for fossil diesel were 192 ppm. At the average biodiesel produced 33% higher nitrogen oxides than fossil diesel. The reason for this is the higher adiabatic flame temperature, less radiative heat transfer, decrease in ignition delay, higher degree of unsaturation, and higher oxygen content. The abundance of oxygen and the high ignition temperature resulted in the formation of NOx emissions.[20]

P. Shrivastava et al. show the nitrogen oxides increased with increase in the load for all the fuels selected. The reason for this increase was the increase in the temperature of the exhaust gases. There were reductions in nitrogen oxide emissions for biodiesel compared to fossil diesel. The researcher found that the NOx emissions for Karanja biodiesel increase for B20, B10, and B100; were 3.83%, 11.61%, and 22.42%, respectively compare to diesel. For Roselle biodiesel NO_X increase for B20, B10, and B100, they were 6.01%, 12.63%, and 16.54% respectively at full load compare to diesel.[24]

S. A. E. K.A. Abed et al. achieved the NOx emissions of biodiesel are higher compared to fossil diesel. Where the researcher explained that the increase in nitrogen oxides emissions with the increase in the engine load resulted from the high temperature inside the combustion chambers and a higher adiabatic flame temperature. [32]

S. Imtenan et al concluded that with decreasing speed, emissions for all combinations do not increase. The reason for this is the increase in the period of burning time when the speed becomes lower. B20 showed the highest level of NO_X, due to the higher level of oxygenation.[33]

U. Rajaka et al. showed the dependence of nitrogen oxides emissions on the oxygen content of the fuel, the combustion temperature, and the effective volume of the combustion zone. There are many factors that affect the proportion of nitrogen oxides in the exhaust, combustion pressure, engine load, oxygen content, temperature, mixture density, and mixture homogeneity. The researcher found that fossil diesel fuel has higher nitrogen oxide emissions than other B20, B40, B60, B80, and B100 mixtures. The researcher found that there are nitrogen oxides emissions of less than 4.9% and 26.64% B20 and B40 as compared to fossil diesel.[34]

E. Buyukkaya et al. Investigated nitrogen oxides decrease with increasing engine speed. This is due to increased volumetric efficiency and gas flow inside the cylinder at high speed, which leads to faster fuel-air mixing and better combustion. The increase in nitrogen oxide emissions was 12% compared to fossil diesel. For B20 and B70 the incease was, 6% and 9%, respectively compare to diesel. [35]

P. Appavu et al. showed NO_X emissions are delicate to the presence of oxygen. The spray characteristics depend on the droplet size, droplet momentum, mixing rate, penetration rate, evaporation rate, and heat transfer rate. Biodiesel causes a significant increase in nitrogen oxide emissions compared to fossil diesel. The rate of nitrogen oxide emissions for biodiesel was 6%. The main reason is the variation in the mixing ratios, droplet size, and engine geometry.[36]

L. A. Raman et al. achieved the concentration of nitrogen oxides decreases with the increase in brake power. The NOx concentration decreased significantly at the maximum brake power, and the NOx concentration was observed to be 14.4%, 21.6%, 28.5،% and 32.9% for B25, B50, B75, and B100, respectively, compared to the fossil diesel. An increase in the cetane number and the oxygen content and the decrease in the calorific value led to an increase in the concentration of nitrogen oxides in the exhaust gases. Increasing the ignition delay of biodiesel enhances the combustion of the pre-mixed mixture by injecting more fuel before ignition, and this may be a reason for increasing the oxygen content.[37]

2.6.2 Hydrocarbon (HC) Emission

S. Bari et al. used Cussons single-cylinder engine testbed model P8160. According to the study, the non-combustible hydrocarbon is one of the most important emissions. Hydrocarbon emissions depend on engine operating conditions and fuel characteristics. The average unburned HC for biodiesel was 47 ppm and for fossil diesel 100 ppm for full engine speed. As HC emissions decreased by 55% in biodiesel than in fossil diesel, this is an indication of better oxidation of hydrocarbons due to the higher cetane number and higher oxygen content.[20]

J. N. Nair et al. used a single-cylinder, four-stroke, constant speed, water-cooled, diesel engine. As a result of insufficient temperature in the penetration chamber, hydrocarbon emissions are formed due to the lack of total combustion. In fat-free mixtures, the flame speeds are so low that combustion does not occur in the energy run and may not even occur. The emissions in biodiesel are lower than the fossil diesel with rates B10 was 17%, B20 was 10%, and B30 was 9%.[28]

L. A. Raman et al., used a stationary, vertical cylinder, four-stroke direct injection diesel engine. Hydrocarbon emissions for B25, B50, B75, and B100 decreased by 15.4, 26.7, 32.2, and 42.1% respectively compared to fossil diesel at maximum brake power. The fuel must be mixed and decomposed to burn better. Therefore, the high oxygen content of biodiesel makes the hydrocarbon emissions less.[37]

S. Simsek investigated using a naturally aspirated, air-cooled, single-cylinder, four-stroke, direct injection diesel engine with a fixed speed of 3000 rpm engine. HC emissions decreased by 1.29%, 4.43%, 8.23%, 11%, 14.42% and 17.49% for B10, B20, B30, B50, B75 and B100 fuels respectively compared to fossil diesel fuels. The percentage of emissions decreases with the increase in the percentage of biodiesel in the mixture. The reason for this decrease is due to the high oxygen content in biodiesel.[26]

P. Appavu et al. utilized a 4-stroke, 1-cylinder, naturally aspirated, water-cooled, direct injection diesel engine. According to the study, biodiesel produced from palm oil reduces HC emissions compared to fossil diesel due to the accessibility of oxygen atoms in biodiesel. Where the percentage of lower HC emissions of biodiesel was 26% compared to fossil diesel.[36]

K. Muralidharan et al. used Single cylinder, four-stroke, variable compression ratio multi-fuel engine coupled with eddy current dynamometer for loading. The higher the load, the higher the HC emissions in all mixtures except for B20. The reason for this is the spraying quality and high viscosity of the fuel that produces some of the hydrocarbons in biodiesel. B60 and B80 fuel blends produce 50% and 75% lower hydrocarbon emissions than fossil diesel fuels.[38]

2.6.3 Carbon Monoxide (CO) Emission

S. Bari et al. used Cussons single-cylinder engine testbed model P8160. Carbon monoxide is produced from incomplete combustion of fuel. Carbon monoxide emissions depend on the air-to-fuel ratio. The researcher found that the reduced air-to-fuel ratio with increased load reduced the conversion of carbon monoxide to carbon dioxide, which led to an increase in carbon monoxide emissions at higher brake power. The combustion of biodiesel emits 51% less carbon monoxide than fossil diesel. The reason for this is the high percentage of oxygen in biodiesel compared to fossil diesel.[20]

J. N. Nair et al. used a single-cylinder, four-stroke, constant speed, water-cooled, diesel engine. The main reason for the emission of carbon monoxide is the incomplete oxidation of carbon resulting from partial combustion. Because of biodiesel contains more oxygen than fossil diesel, carbon monoxide is converted to carbon dioxide. The emissions for B10 are 26%, B20 is 22% and B30 is 5% lower compare to diesel fuel.[28]

L. A. Raman et al. used a stationary, vertical cylinder, four-stroke direct injection diesel engine. At lower loads, the CO emission is higher than the full load engine running. The main reason for this is that the fuel is rich in high loads. Biodiesel produced emissions at the mixtures B25, B50, B75, and B100 were (7.6, 22.7, 30.4, 35.4) % lower respectively at full load compare to diesel. As the presence of oxygen in abundance helps combustion and reduces carbon monoxide emissions.[37]

S. Simsek investigated using a naturally aspirated, air-cooled, single-cylinder, four-stroke, direct injection diesel engine. Regarding engine load, the percentages of carbon monoxide emissions decrease were 13.30%, 18.23%, 21.33%, 25.68%, 30.77% and 34.28%, for B10, B20, B30, B50, B75 and B100 mixtures, respectively. Because biodiesel contains higher cetane and a higher oxygen component, the combustion is complete.[26]

P. Appavu et al. utilized is a 4-stroke, 1-cylinder, naturally aspirated, water-cooled, direct injection diesel engine. The lack of oxygen is the main reason for the formation of carbon dioxide, and because biodiesel contains a high percentage of oxygen, emissions of carbon monoxide are low compared to fossil diesel. there is a 25% reduction in carbon monoxide emissions of biodiesel.[36]

K. Muralidharan et al. used Single cylinder, four-stroke, variable compression ratio multi-fuel engine coupled with eddy current dynamometer for loading. The researchers found that the carbon monoxide emission of the B40 mixture is very close to the carbon monoxide emission of fossil diesel. The percentage of monoxide increases with the increase in the temperature inside the combustion chamber, the air-fuel ratio, the physical and chemical properties of the fuel, the shortening of the combustion time, and the lack of oxygen at high speed. Increasing the viscosity of biodiesel could lead to a slight increase in carbon monoxide emissions.[38]

2.6.4 Carbon Dioxide Co_2 Emission

Ankur Nalgundwar et al. showed carbon dioxide is formed when there is enough oxygen in the stage of the formation of carbon monoxide. In lower biodiesel mixtures B10 and B20 the emissions were an increase compared to diesel fuel by 2.6% and a decrease over fossil diesel by 4.1%, respectively. High biodiesel mixtures B40, B40, B50, B60 and B80 and biodiesel showed 20.2%, 21.5%, 24.6%, 27.9%, 28.9% and 42.3% compared to fossil diesel.[6]

S. A. E. K.A. Abed et al. used a four-stroke single-cylinder diesel engine. The higher the load, the higher the CO_2 emissions due to the higher fuel consumption. Also, emissions of carbon dioxide have decreased compared to fossil diesel. The reason for this decrease is due to the higher oxygen content in biodiesel compared to fossil diesel.[32]

P. Shrivastava et al. used A four-stroke, single-cylinder, diesel engine. The emission results for Roselle biodiesel for the B10 B20 and B100 blends were 817.99, 804, and 834.5 g / kWh. While the emissions for Karanja biodiesel B10, B20, and B100 were 832, 792, and 811 compared to fossil diesel, 774 g / kWh. As it turns out, carbon dioxide emissions are higher in biodiesel compared to fossil diesel. This is due to the diesel's high calorific value.[24]

Erkan Öztürk showed No significant difference was observed in the carbon dioxide emissions of biodiesel. Carbon dioxide emissions increase with the increase in engine load. Also, the emissions of carbon dioxide increase at the total load due to the lack of oxygen at the total load. The researcher concluded that carbon monoxide emissions increase or decrease according to the improvement of combustion.[39]

Z. Utlu et al. The compression ignition engine used Land Rover TDI 110. Fossil diesel emissions of CO_2 were 10.6 ppm and biodiesel was 10.2 ppm at 3500 RPM. The decrease was 10% in biofuel emissions compared to fossil diesel at 3,000 RPM. The average reduction in biodiesel emissions was 8.05% compared to that of fossil diesel.[18]

2.6.5 Exhaust Gas Temperature

C. Haşimoğlu et al. showed at low speeds (1100–1400 rpm), the exhaust gas temperature (just before turbine inlet) was reduced from 12.8 to 2.7, while at medium and high engine speeds (1600–2800 rpm), the exhaust gas temperature (before the turbine intake) was reduced from 18.9 to 1.6 %. In the LHR biodiesel state, the exhaust gas temperature (just before turbine inlet) was reduced from 14.7 percent to 2.12 percent at low engine speeds (1100–1600 rpm), and from 8.3 percent to 18 percent at medium and high engine speeds. At all engine speeds, the exhaust gas temperature (before the turbine inlet) rises by 13% in LHR diesel mode. As previously stated, biodiesel has a lower heating value than diesel fuel by around 14%, resulting in a lower exhaust gas temperature in the STD biodiesel condition. In the case of LHR biodiesel, even though the temperature rises owing to heat insulation, the rise is limited due to the reduced heating value of biodiesel.[40]

2.7 Summary For Tranesterfication Process

Author	Vegetable oil type	Transesterification reaction conditions	Result
1- M. Singh and Sandhu [41]	Argemone oil	• MeOH:oil 6:1 • 0.5 wt% Catalyst • 1.5 hour • Reaction temperature 60–65 °C	• 95% biodiesel • Density 0.85 g/ml • Kinematic viscosity 4.38 cSt • Flash point (°C) 193 • Calorific value (MJ/kg) 37.5
2- S. Ramalingam and N. V. Mahalakshmi [42]	Moringa Oleifera oil	• MeOH:oil 6:1 • 1.8 wt% Catalyst • 2 hour • Reaction temperature 55 °C • 600 RPM	• 96.71% biodiesel • Density 0.867 g/ml • Flash point (°C) 156 • Calorific value (MJ/kg) 39.54 • Kinematic viscosity 4.97 cSt
3- Sundar K. and Udayakumar [43]	Cotton seed oil	• 1L oil • 250 ml methanol • 13g NaOH • 1 hour-600rpm • Reaction temperature 60 °C	• Density 0.89 g/ml • Calorific value (MJ/kg) 39.49 • Cetane Number 54.0 • Kinematic viscosity 5.8 cSt

4- Medhat Elkelawya et al. [44]	used frying oil	• 1 kg oil • 240 g methanol • 8 g NaOH • Reaction temperature 65 °C	• Cetane number 55 • Density 0.883 g/ml • Flash point (°C) 176 • Calorific value (MJ/kg) 38.5 • Kinematic viscosity 5.3 cSt
5- Ankur Nalgundwar et al. [6]	jatropha oil	• 1L oil • 250 ml methanol • 5g NaOH • 90 minutes time reaction • Reaction temperature 60 °C	• Density 0.8649 g/ml • Calorific value (MJ/kg) 39.847 • Kinematic viscosity 5.48 cSt
6- S. Radhakrishnan et al.[45]	palm oil	• MeOH:oil 6:1 molar ratio • 0.3 wt% KOH • 60 ºC reaction temperature • 45 min time reaction • 340 rpm	• Density 0.855 g/ml • Calorific value (MJ/kg) 41.312 • Cetane Number 60 • Kinematic viscosity 4.5 cSt • Flash point 172 ºC
7- Yuvarajan Devarajan et al. [46]	waste cooking-oil	• 500 ml oil • 250 ml methanol • 2.5 g NaOH • 45 minutes time reaction	• Density 0.8829 g/ml • Calorific value (MJ/kg) 38.108 • Cetane Number 52 • Kinematic viscosity 4.3

		• Reaction temperature 60 °C	
8- Prabhu Appavu et al. [36]	Palm oil	• 1L oil • 200 ml methanol • 10g NaOH • Reaction temperature 45 °C	• Density 0.870 g/ml • Calorific value (MJ/kg) 38.3 • Cetane Number 54 • Kinematic viscosity 5.3 cSt • Flash point 178 ºC
9- Mohammad Ali Amani et al. [15]	Date seed oil	• 50 g oil • 11 g methanol • 0.375 g NaOH • 2 h time reaction • Reaction temperature 60-65 °C	• Density 0.877 g/ml • Number 60.3 • Kinematic viscosity 3.8 cSt • Flash point 130 ºC
10- K.A. Abed et al. [47]	waste cooking-oil	• MeOH:oil 6:1 molar ratio • 1 wt% KOH • 65 ºC reaction temperature • 90 min time reaction	• Density 0.892 g/ml • Calorific value (MJ/kg) 42.835 • Cetane Number 63.63 • Flash point 176 ºC

From above table the results show the best type of vegetable oil was waste cooking oil because it is cost and do not effect on the price of oil for human consumption.

2.8 Engine Performance and Exhaust Emission Summary

Author	Engine description	Engine performance results	Exhaust emission results
1- S. Bari and s. N. Hossain [20]	5 kW Cussons air-cooled single-cylinder indirect-injection diesel engine with a Ricardo comet-type-swirl combustion chamber	• Brake thermal efficiency of biodiesel is less than that of diesel, as the highest percentage of biodiesel was 20% • the brake specific fuel consumption of biodiesel was 10% higher than that of fossil diesel	• higher NOx emissions • biodiesel emits 51% less carbon monoxide than fossil diesel • HC emissions decreased by 55% in biodiesel than in fossil diesel
2- J. N. Nair et al. [28]	single-cylinder, four-stroke, constant speed, water-cooled, diesel engine.	• Diesel are showing higher brake thermal efficiency than biodiesel • brake power, biodiesel can substitute diesel in the form of blends as there is no important drop in engine performance	• CO and, HC, emissions of biodiesel are decreasing than fossil diesel.

		• B10 shows higher performance and lower emissions than further blends and fossil diesel	
3- P. Shrivastava et al. [24]	In this study, the experiments were conducted on a four-stroke, single-cylinder, diesel engine	• BTEs found for the different fuels at low, medium and full load conditions and were better for B20 as compared to the other blends. • brake specific fuel consumption increased with increasing the ratio of biodiesel in the blends. BSFCs were higher by 14.6% for B100 compared with the diesel fuel. • volumetric efficiency higher for biodiesel and its blends than diesel.	• NOx emissions were lowered compared to fossil diesel. It was shaw that NOx emissions increased with the increase in load • CO_2 emissions were showed to be higher for biodiesels and its blends than fossil diesel. • EGT was slightly lower
4- Suleyman Simsek [26]	A naturally aspirated, air-cooled, single-cylinder, four-stroke, directinjection	• Brake thermal efficiency was observed to decreased for B100 blend	• exhaust gas temperatures for biodiesel were lower than that for diesel fuel.

	diesel engine with a fixed speed of 3000 rpm engine	compared to diesel fuel. • Brake specific fuel consumption increased fuel blends compared to diesel fuel	• biodiesel reduced CO, HC emissions and increase NOx emissions.
5- Mandeep Singh et al. [41]	4-stroke, 4-cylinder, turbocharged inter-cooled CI engine	• BTE decrease with increase ratio of biodiesel in blend. • higher BSFC for biodiesel compare to diesel fuel.	• HC and CO emissions decrease with increase in ratio of biodiesel • NOx emissions was higher for biodiesel compare to diesel fuel
6- S.Imtenan et al. [33]	YANMAR TF 120-M diesel engine mounte	• Compare to diesel fuel biodiesel was lower engine brake power, higher BSFC and lower BTE	• Higher CO emission compare to disesl fuel higher NO lower HC
7- J. Jayaprabakar [30]	constant speed, four stroke, vertical, and air cooled Diesel engine	• the volumetric efficiency for biodiesel is lesser than Diesel • Biodiesel has more fuel consumption than the fossil diese • fossil diesel has higher brake	• NOx emissions increase with the increase biodiesel ratio in blends

		thermal efficiency than the biodiesel	
8- Duple Sinha et al. [27]	This researcher used a four-stroke, single-cylinder, air-cooled, and direct injection diesel	• brake thermal efficiency of biodiesel is lower for all mixtures than for fossil diesel • consumption of biodiesel was higher than the consumption of fossil diesel for the same resulting power	• lower CO and HC emission for biodiesel compre to diesel fuel
9- Magı´n Lapuerta et al. [32]	Four cylinders automotive engine	• An increase in BSFC for biodiesel compare with diesel fuel • Decrease brake thermal efficiency • decrease in brake power with biodiesel	• increases NOx emissions for biodiesel fuels • CO emission found decrease with biodiesel
10- Bibin C. et al. [48]	a single-cylinder four-stroke diesel engine	Compare to diesel fuel • Decrease BTE • Increase BSFC	Compare to fossil diesel • decrease CO emission • Increase CO_2 emission • increase NOx emission • decrease EGT • decrease HC emission

11- H. Raheman et al. [22]	a single cylinder, four stroke, water cooled Ricardo E6 engine	• brake specific fuel consumption • increased brake thermal efficiency decreased with increase in the proportion of biodiesel in the blends	• CO in exhaust emissions decrease • NOx increased with increase biodiesel content in the blends
12- M.S. Gad [23]	single cylinder, four stroke, air cooled, direct injection, naturally aspirated	Brake Thermal efficiency of biodiesel lower compared to diesel fuel and brake specific fuel consumption was higher	• Higher exhaust gas temperatures • CO and HC were decrease • NO_X emissions increased

CHAPTER THREE

EXPERIMENTAL WORK

3.1 Introduction

In this chapter, the experimental equipment and measuring tools that were used to evaluate the effect of adding various types of renewable fuels to a compression-ignition engine on performance and emitted pollutants concentrations in comparison to diesel are described. The TD202 Small Engine Test Set is an instrumented engine test set for testing small single-cylinder engines such as lawn mowers, cultivators, pumps, and generators. A sturdy hydraulic dynamometer with simple operation is included in the test package to load the engine.This dynamometer is efficient, no large electrical supplies or load resistors are needed because the engine power is dissipated into the water that passes through the dynamometer.

3.2 Preparing Biodiesel

3.2.1 Materials and Methods

6 moles of methanol react with 1 mole of palm olein oil (most used oil in Iraq), yielding 6 moles of biodiesel and 1 mole of glycerol. These ratio based and academic research [49][50]. Palm olein oil was bought from a local market. In each process, 50 grams were used. Methanol with a purity of 100 percent was used sodium hydroxide also used. Sulfuric acid with a purity of 95% was utilized as a catalyst in the treatment step. Baker, magnetic stirrer, thermometer, and separation funnel are some of the other important materials.

3.2.2 Acid-catalyzed esterification

Among the most influencing factors in the esterification reaction is the molar ratio of methanol to oil, reaction time, acid catalyst quantity, and temperature.

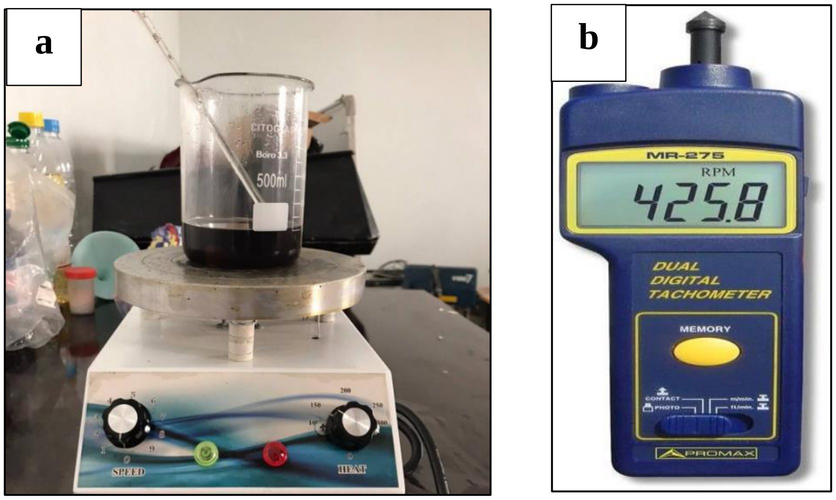


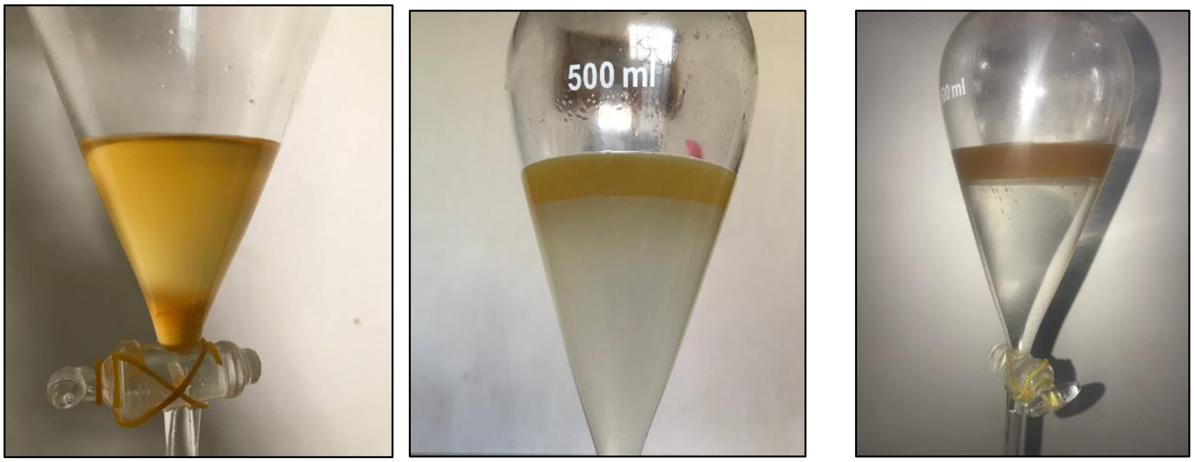
Figure 3-1 acid-catalyzed esterification a) magnetic stirrer b) Mechanical contact hand Tachometers

50 g of oil was poured, then sulfuric acid was added to the catalyst and followed by methanol. The molar ratio of methanol to oil was 3:1. The mixture was heated to a temperature of 60 ºC and stirred at 250 rpm by the magnetic stirrer for 60 minutes. The proportion of H_2SO_4 was 0.25 wt%. After the completion of the reaction, the mixture is heated to a temperature of 65 ºC for 25 minutes to evaporate the methanol and dispose of it. When the completion of these steps, the percentage of free fatty acids have decreased by 5%.[12]

3.2.3 Transesterification process

11g of methanol was placed in a beaker and 0.375g NaOH was added and with continuous stirring for 10 minutes, to form sodium methoxide. 50g

Palm olein oil is heated and when it reaches a temperature of 60 ºC, sodium methoxide is poured over palm olein oil and left under constant stirring 300 rpm by a magnetic stirrer for 2 hours where the molar ratio methanol: palm olein oil 6:1. After the reaction ends, the mixture is left for 8-12 hours until it separates into two layers, which are the biodiesel upper layer and the glycerol lower layer. The two materials of different densities can be separated by a separating funnel. [15]



(a) (b) (c)

Figure 3-2 a) biodiesel separation b)wash process c) final step of the washing

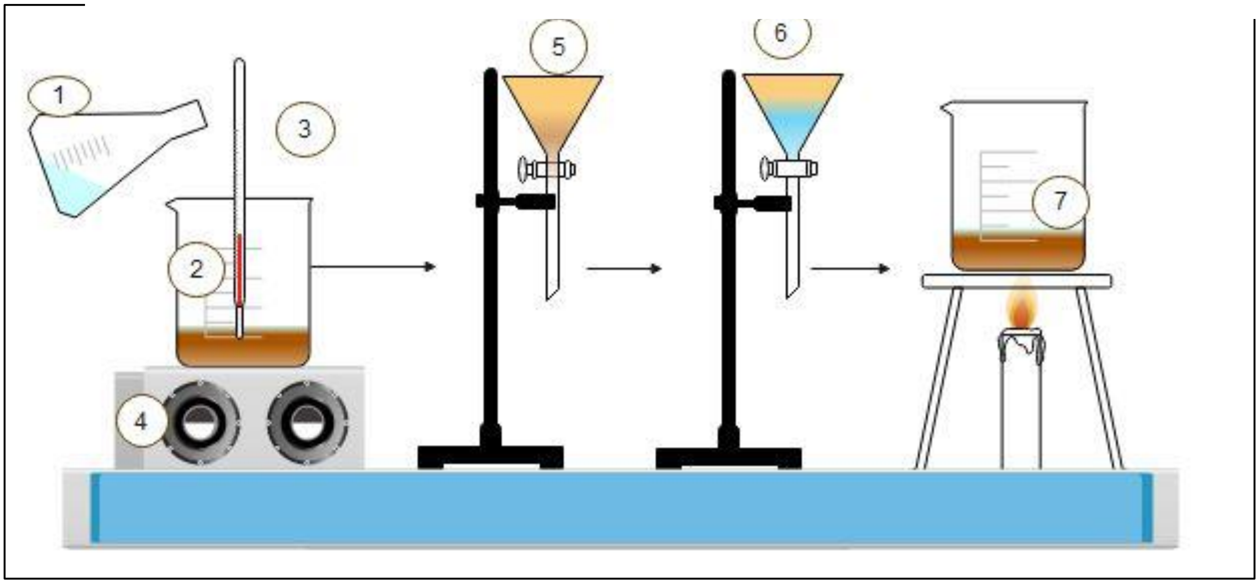


Figure 3-3 Transesterification steps 1- methoxide 2-vegetable oil 3-thermometer 4-magnetic stirrer 5-separation process 6-washing process 7-drying process

The biodiesel process is carried out after separation by pouring water at a temperature of 70 ºC to get rid of methanol and the catalyst. This process is repeated several times as needed. The biodiesel is dry by heating it at 110 ºC for 25 minutes to remove water content.

3.2.4 Fuel Characterizations

The density of the biodiesel was measured with the hydrometer at 25 ºC and the Pensky martens flashpoint tester use to measure flash point (ASTM D93). Viscosity was measured using a viscometer at 40 C. The calorific value of the fuel was also measured using a Bomb calorimeter.

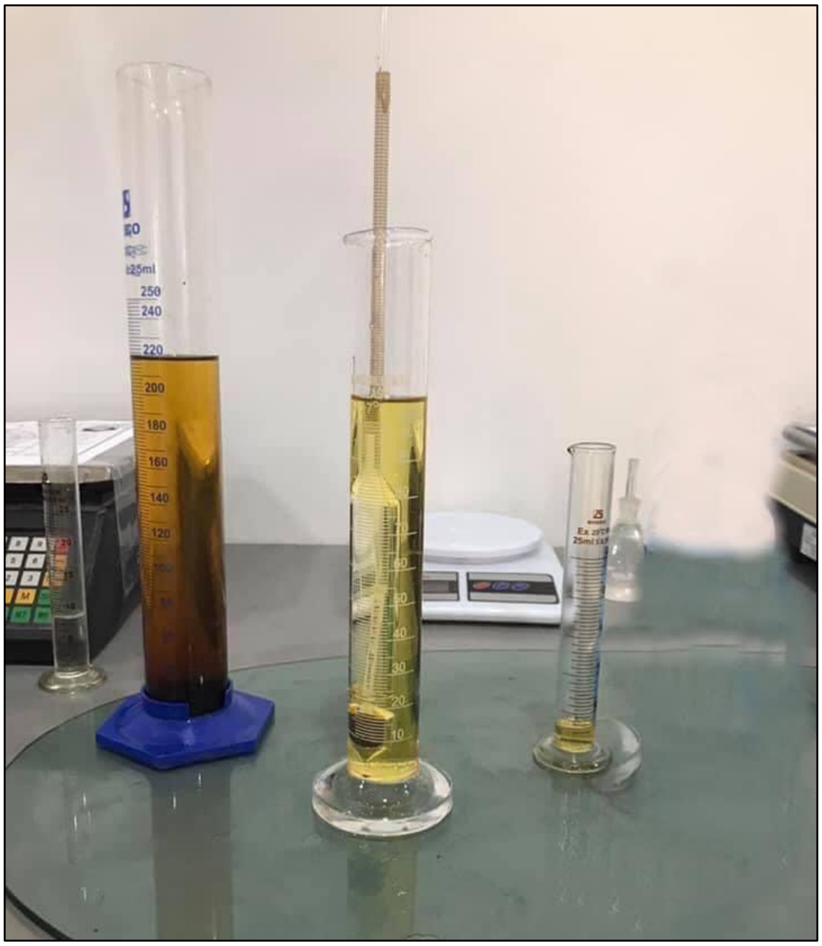


Figure 3-4 biodiesel density Characterization by hydrometer

Figure 3-5 flash point test by Pensky martens flash point tester**.**

3.3 Experimental setup

The equipment is fully compatible with TecQuipment's Versatile Data Acquisition System (VDAS), that is available separately as show in figures (3.6) and (3.7). Using the VDAS enables accurate real-time data capturing, monitoring, and displaying and calculating of all relevant parameters on a computer, (PC available separately) making tests quick and reliable.

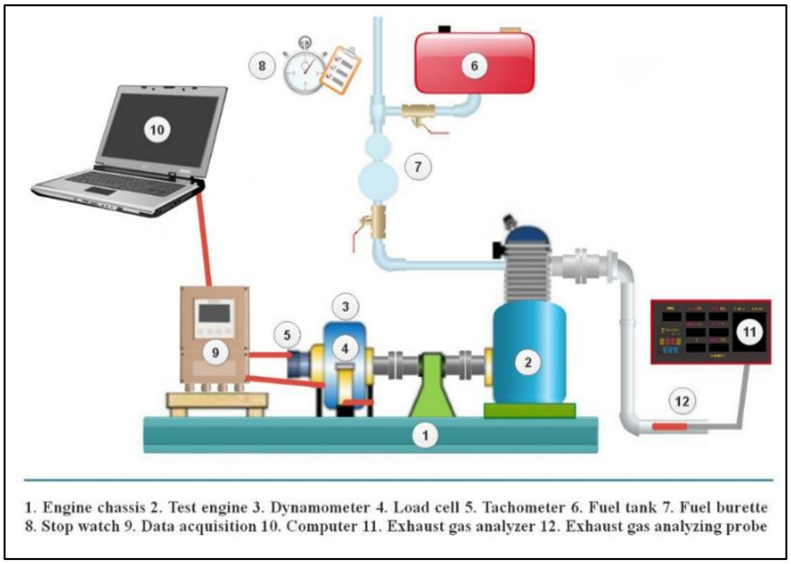
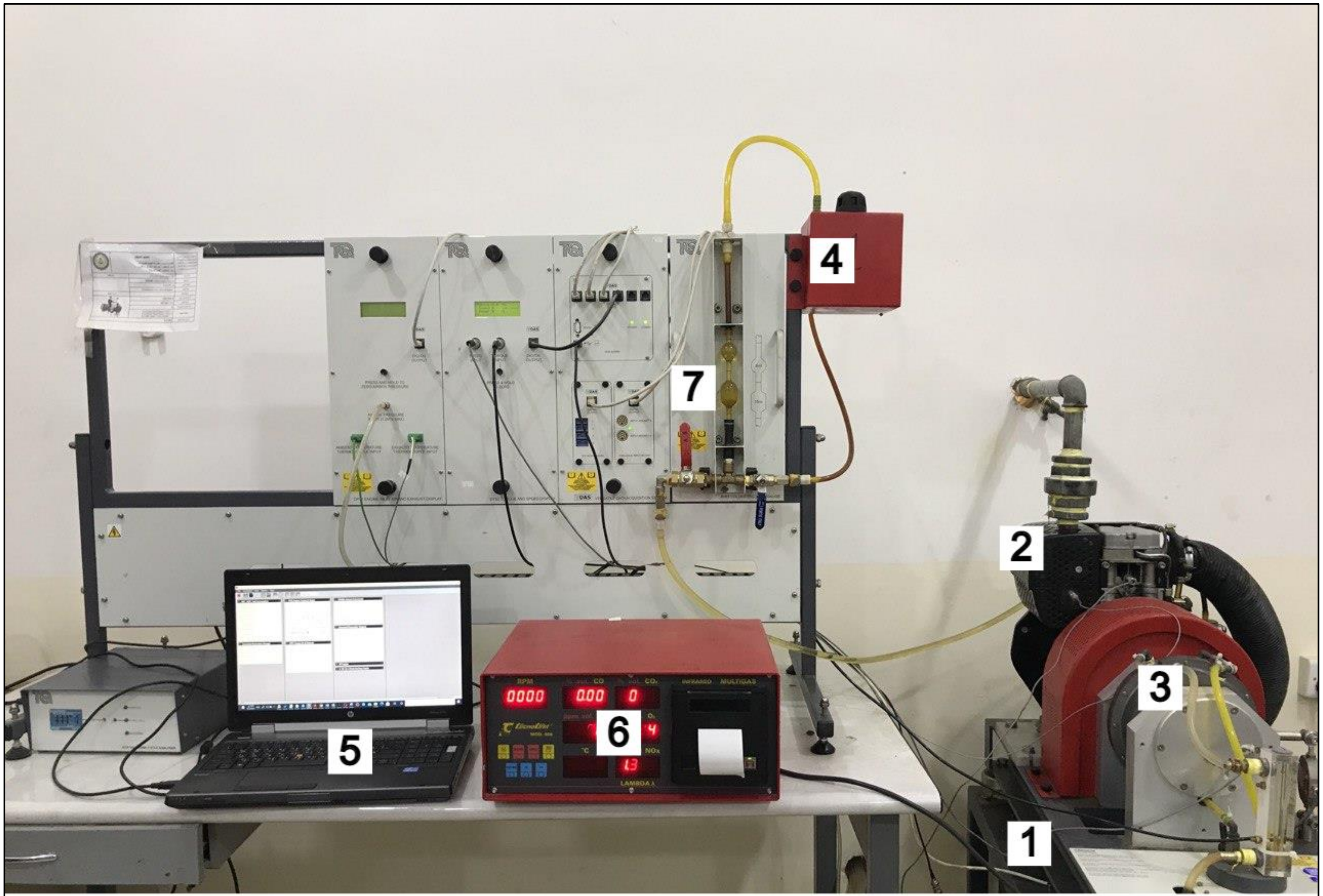


Figure 3-6 Schematic diagram of the components of experimental rig.



1- engine chasis 2- test engine 3- dynmometer 4- fuel tank 5- computer
6- exhuast gas analyzer 7- fuel burette

Figure 3-6 The actual scheme of the experiment

3.3.1 Test Engine Description

The TD202 made from a small air-cooled single cylinder diesel engine with:

- Overhead valves - one for inlet, one for exhaust
- Direct fuel injection
- Pressurized oil lubrication
- Recoil starter

The engine includes a governor that prevents the engine exceeding its optimum speed. The governor is a device inside the engine, linked to the fuel injection system. When the engine speed increases to a certain level, the governor forces the fuel injection system to reduce the amount of fuel that enters the cylinder. This regulates the maximum speed and engine power.

The engine is lubricated by ordinary engine oil, stored in a small sump at the base of the engine body. The oil is pressurised and forced around the engine, to lubricate its moving parts and bearings. The oil passes through a fine mesh oil filter that helps to clean the oil.

The engine is based on the standard cross-flow design, so that the fuel/air mixture enters from one side of the cylinder head and is forced out as exhaust to the opposite side of the cylinder head.

Forced air-cooling is provided by the fins around the engine flywheel. As the flywheel turns, the fins force air around the cylinder by means of simple ducting.

The engine is started by a starter handle and cord, wrapped around a pulley on the flywheel. The pulley includes a clutch to disengage the cord and pulley when the engine starts. This arrangement is called a 'recoil starter'.

The engine includes a speed control (often called a 'rack'). The rack directly adjusts the amount of fuel that can enter the cylinder. If the rack is moved to the minimum position, no fuel is injected to the cylinder and the engine stops. Alternatively, an engine stop button is provided. This button stops the fuel injection system.

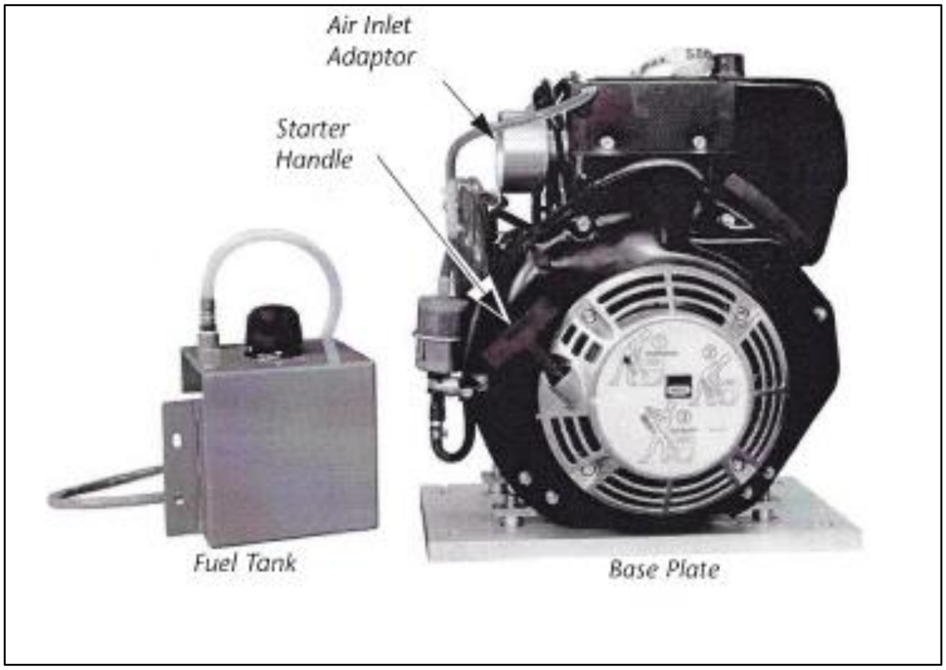


Figure 3-7 TD202 small engine

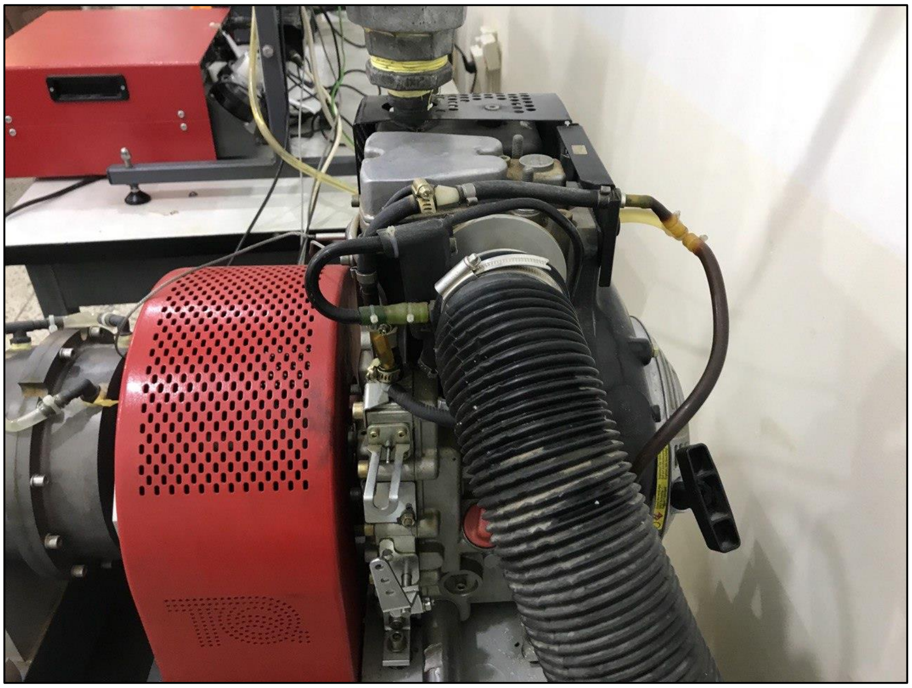


Figure 3-8 The engine used in the study

3.3.1.1 Technical details

Table 3-1 Technical details of test engine

Items	specification
Dimensions	Width 400 mm Height 450 mm Depth 350 mm
Net weight	35 kg
Fuel type	Diesel
Fuel tank	Caramel/light brown-painted steel with vent and filter cap
Absolute maximum power	3.5 kW (4.8 hp) at 3600 rev.min^{-1}
Continuous rated power	3.1 kW at 3000 rev.min^{-1}
Bore	69 mm
Stroke/crank radius	62 mm/31 min
Connected rod length	104 mm
Engine capacity	232 cm^3
Compression ratio	22:1
Oil type	Multigrade SAE 5 W-40
Oil capacity	2.6 Litre

3.3.2 The Hydraulic Dynamometer

Hydraulic dynamometer supplied as default to the testbed is a trunnion installed Hydraulic Dynamometer which applies load depending to the water flow rate and amount of water in its casing. An accurate needle valve regulates the flow rate and level. The torque is monitored by means of an electronic load cell built into the side of the dynamometer. The dynamometer rotational speed is measured electronically by means of an optical sensor.

The hydraulic dynamometer is a simple but efficient way to load a test engine. It is made up of two shells with radial ribs on the inside. A shaft that travels through the dynamometer is linked to a rotor with radial ribs on both sides. To allow the casing to act to a strain gauged load cell, the dynamometer is positioned in self-aligning bearings. Water enters the dynamometer through an adjustable needle valve at the top and exits through a drain at the bottom. A vent allows extra air and water to escape.

The ribs on the casing and rotor force the water to churn while the engine turns the shaft. The load cell measures the resistive torque as a result of this. Adjusting the water flow rate changes the amount of resistance, as does the height of the water in the casing. The constant flow of water through the dynamometer dissipates the heat generated by the churning of the water. The needle valve is used to control the dynamometer indirectly (an open-loop system). Despite the fact that the load control is an open-loop system, the speed can be maintained at around 100 rev/min.

A flowmeter was added to control the load of the engine (flowing water to the dynamometer), as it shown in figure (3.9)

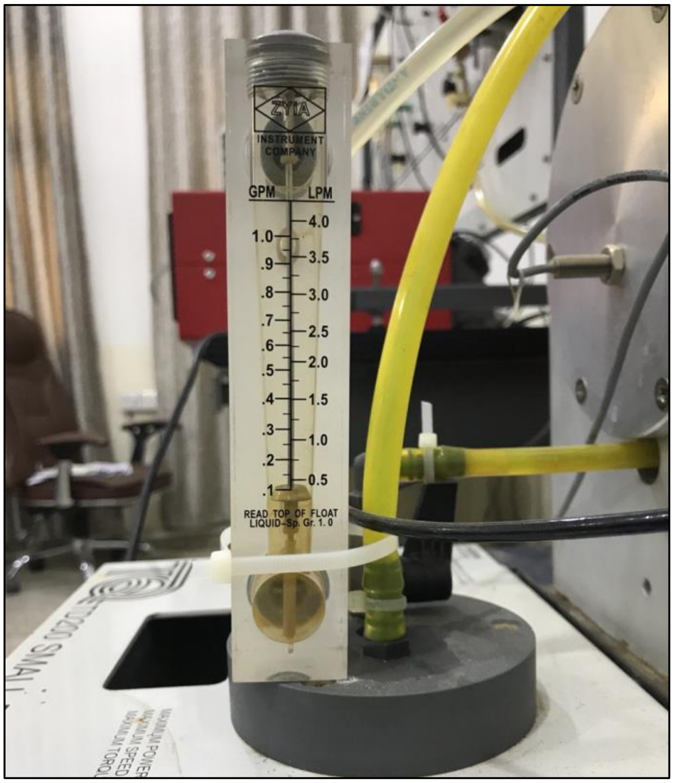


Figure 3-9 Flowmeter controls the amount of water inlet into the dynameter**.**

3.3.3 Instrument Frame

The TD202 small engine test set's instrument modules are installed on the instrument frame. To power the Instrument Modules, the frame contains a single IEC type power inlet and many IEC type outlets. To prevent vibration transmission from the engine to the measuring devices, the instrumentation and test bed are maintained separate.

3.3.4 Instrument Modules

3.3.4.1 Torque and Speed Display - DTS2

The torque measured on the dynamometer and the speed computed from the optical sensor pulses are displayed in this module (with time). The product of speed and torque is used to compute power show figure (3-13).

3.3.4.2 Engine Inlet Air and Exhaust Display - DPT1

The ambient (barometric) pressure and temperature, as well as the pressure inside the airbox, are displayed in this module. The airbox orifice dimensions, as indicated in fig. (3.10), and the pressure differential between the ambient and inside the airbox are used to compute the engine inlet airflow (Ap).

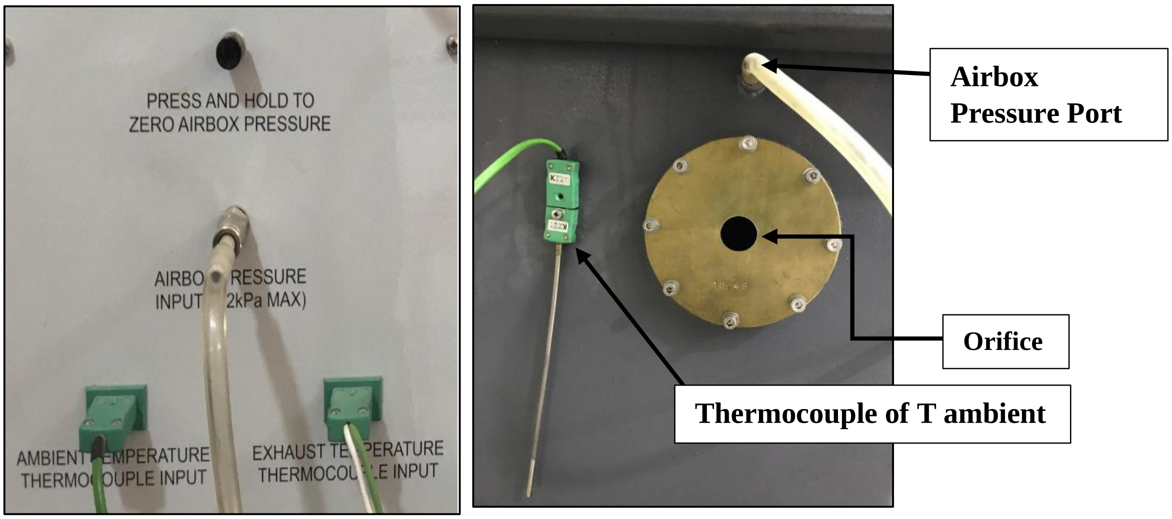
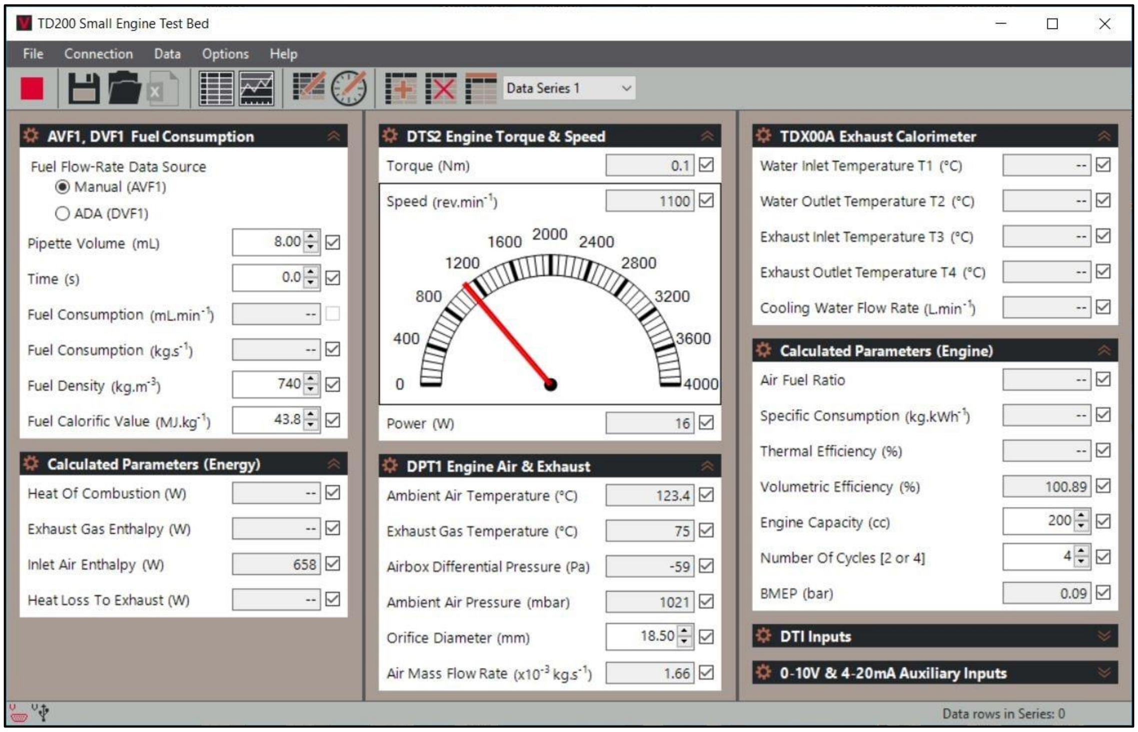


Figure 3-10 Airbox Pressure Port and Orifice.

3.3.4.3 Versatile Data Acquisition System – VDAS

The VDAS apparatus from TecQuipment can be used with the Small Engine Test Set and its Instrument Modules. The VDAS equipment consists of two parts (hardware and software) that enable the user to:

- Reduce errors
- Save experiment time
- Record the test results on a suitable computer
- Automatically calculate important values
- Produce high-quality graphs and results, as well as the ability to export data to a spreadsheet software for further graphing and analysis. The VDAS software and hardware are shown in Figures (3.11) and (3.12).



AVF1, DVF1 Fuel Consumption

Fuel Flow-Rate Data Source
● Manual (AVF1)
○ ADA (DVF1)
Pipette Volume (mL): 8.00 ☑
Time (s): 0.0 ☑
Fuel Consumption (mL.min^{-1}): -- ☐
Fuel Consumption (kg.s^{-1}): -- ☑
Fuel Density (kg.m^{-3}): 740 ☑
Fuel Calorific Value (MJ.kg^{-1}): 43.8 ☑

Calculated Parameters (Energy)

Heat Of Combustion (W): -- ☑
Exhaust Gas Enthalpy (W): -- ☑
Inlet Air Enthalpy (W): 658 ☑
Heat Loss To Exhaust (W): -- ☑

DTS2 Engine Torque & Speed

Torque (Nm): 0.1 ☑
Speed (rev.min^{-1}): 1100 ☑
Power (W): 16 ☑

DPT1 Engine Air & Exhaust

Ambient Air Temperature (°C): 123.4 ☑
Exhaust Gas Temperature (°C): 75 ☑
Airbox Differential Pressure (Pa): -59 ☑
Ambient Air Pressure (mbar): 1021 ☑
Orifice Diameter (mm): 18.50 ☑
Air Mass Flow Rate (x10^{-3} kg.s^{-1}): 1.66 ☑

TDX00A Exhaust Calorimeter

Water Inlet Temperature T1 (°C): -- ☑
Water Outlet Temperature T2 (°C): -- ☑
Exhaust Inlet Temperature T3 (°C): -- ☑
Exhaust Outlet Temperature T4 (°C): -- ☑
Cooling Water Flow Rate (L.min^{-1}): -- ☑

Calculated Parameters (Engine)

Air Fuel Ratio: -- ☑
Specific Consumption (kg.kWh^{-1}): -- ☑
Thermal Efficiency (%): -- ☑
Volumetric Efficiency (%): 100.89 ☑
Engine Capacity (cc): 200 ☑
Number Of Cycles [2 or 4]: 4 ☑
BMEP (bar): 0.09 ☑

DTI Inputs

0-10V & 4-20mA Auxiliary Inputs

Data rows in Series: 0

Figure 3-11 The VDAS software.

Figure 3-12 The VDAS hardware.

Figure 3-13 torque sensor (load cell)

3.3.5 Volumetric Fuel Gauge - AVF1

The volumetric fuel gauge is the AVF1 (see Fig. 3.14) which is a manually driven fuel pipette that must be used in conjunction with a proper timer or stopwatch.

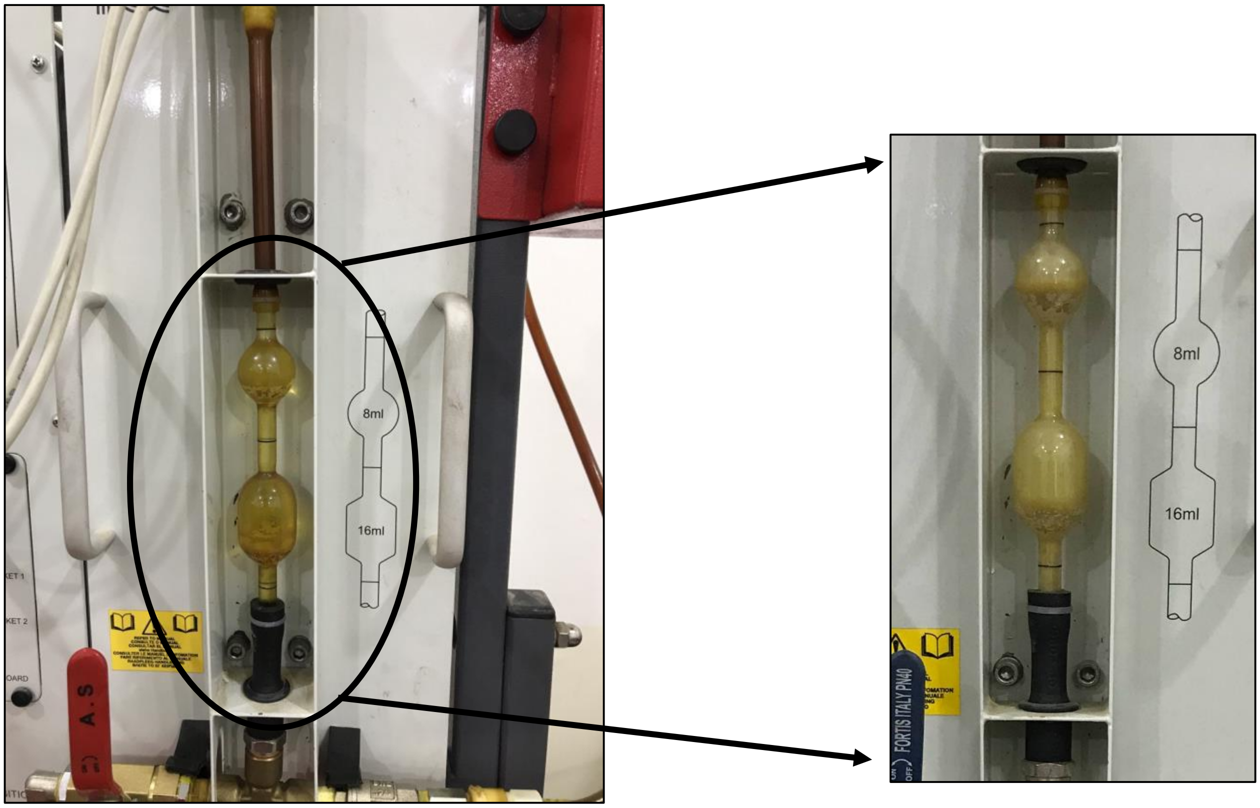


Figure 3-14 The volumetric fuel gauge.

3.4 Gas Analyzer Unit

As demonstrated in fig. (3.15), the Techno test (MOD 488) exhaust gas analyzer is acceptable for petrol engines. It measures, displays, and prints carbon monoxide (CO), carbon dioxide (CO_2), unburned hydrocarbons (HC), and nitrogen oxides (NOx) concentrations. The air/fuel ratio, which is an essential term of reference in engine tuning, is automatically determined based on these parameters. It can also be used to determine engine speed by counting the number of spark plug pulses and monitoring the temperature with a thermocouple probe. The range of measurement and resolution are listed in the table (3.3).

Table 3-2 Range of measurement and resolution for exhaust gas analyses.

Parameter	From	To	Resolution
CO	0	9.99% vol.	0.01%
CO_2	0	19.9% vol.	0.1%
HC	0	9999 ppm	10 ppm
NO_X	0	2000 ppm	10 ppm

Figure 3-15 Gas analysis unit Techno test (MOD 488).

Figure 3-16 Gas analysis unit Techno test (MOD 488).

load applied to the engine, are recorded once the engine reaches thermal equilibrium, and then the emission parameters, such as CO, CO2, HC, and NOx, are recorded. While engine performance like torque, brake power, fuel consumption, brake specific fuel consumption, thermal efficiency, and volumetric efficiency are calculated.

3.5.1 Brake power

The brake power calculated by equation. [51][52]

$$b.p. = 2\pi NT \times 10^{-3}\ [kW] \qquad \text{……(3.1)}$$

Where

N: Engine speed (r.p.m)

T: Torque (N.m)

b.p. : Brake Power

3.5.2 Fuel Consumption

The fuel consumption is determined by measuring the time (t) taken for the engine to consume a given volume of fuel and can be determined by the following equation. [52]

$$\dot{m}_f = \frac{\rho_f \times v \times 10^{-6}}{t} \times 3600\ [\frac{kg}{h}] \qquad \text{……(3.2)}$$

Where:

$\dot{m}_f$: fuel consumption

ρ_f: fuel density (kg/m^3)

t : fuel consumption duration (h)

v : volume of fuel = 2.4×10^{-5} m^3

3.5.3 Brake thermal Efficiency

After the calculation of fuel consumption and power output, the thermal efficiency can be determined as follow.[51]

$$\eta_t = \frac{b.p.}{\dot{m}_f \times Q_{HV}} \times 100 \qquad \text{……(3.3)}$$

Q_{HV}: Lower calorific value

3.5.4 Brake Specific Fuel Consumption

Another key measure derived from the same data is brake specific fuel consumption, which indicates how efficient the engine is at producing work with the fuel given. It's calculated using the formula below.[51]

$$BSFC = \frac{\dot{m}_f}{b.p.} \qquad \ldots..(3.4)$$

3.5.5 The Volumetric Efficiency

The ratio between the amount of air that actually enters the cylinder and the amount of air that could enter under ideal standard atmospheric circumstances is known as volumetric efficiency. It is calculated using the formula below.[51]

$$\eta v = \frac{\dot{m}_{\text{air-actua}}}{\dot{m}_{\text{air-theoretical}}} \qquad \ldots..(3.5)$$

Where:
$\dot{m}_{\text{air-actua}}$: actual air flow rate (kg/s)
$\dot{m}_{\text{air-theoretical}}$: theoretical air flow rate (kg/s)

The amount of theoretical air can be found from

$$\dot{m}_{\text{air-theoretical}} = \frac{2\,N\,\rho_{air} V_d}{n} \qquad \ldots..(3.6)$$

Where:

N: engine speed, n: number of cylinders, V_d : displacement volume, ρ_{air}: density of air.

Experimental Procedure

The test is carried out using two types of fuel, diesel and biodiesel. Diesel fuels and fuel mixtures B10, B20, B50, B70 and B100 were tested by changing the load on the engine (0, 25, 50, 75 and 100%). Exhaust gases are measured using an exhaust gas analyzer to obtain CO, CO_2, HC, and NOx values.

Step 1. The engine speed set at first 1000 rpm.

Step 2. The load was changed from 0% to 100% increased every 25%.

Step 3. The exhaust gas analyzer is warmed up nearly for 15 minutes, then the concentration of CO, CO_2, HC and NOx are recorded.

Step 4. Using a stopwatch, the time fuel consumption during a certain volume (8 ml) was recorded.

Step 5. The exhaust gas temperature was recorded using the VDAS software.

Step 6. The engine characteristics (torque, brake power and fuel consumption) were obtained through VDAS software.

Step 7. Repeat steps from 2 to 6 at 1500 rpm, 2000 rpm, 2250 rpm and 2500 rpm.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Introduction

In this chapter, engine performance and exhaust emissions results are discussed for a single-cylinder diesel engine that runs on fossil diesel fuels and diesel-biodiesel blends, and pure biodiesel. This test was performed in the laboratories of the Technical College of Engineering in Najaf. The brake power, brake specific fuel consumption (BSFC), thermal efficiency, volumetric efficiency, and engine exhaust gas temperature against engine loads from 0% to 100% every 25%. The results of diesel engine emissions (carbon monoxide (CO)) are also studied. Carbon dioxide (CO_2) hydrocarbons (HC) and oxides of nitrogen (NOx)) opposite the engine load.

4.2 Transesterification Results

The transesterification process yielded 44.87 g of biodiesel and 12.43 g of glycerol while losses were 4.075 g. These losses represent the residual catalyst, the unreacted alcohol, and what removed from the emulsion during washing. These are the results of several experiments, as these experiments have shown that the cost of 1 L of biodiesel is less than the cost of 1 L of fossil diesel, as its raw materials are abundantly available in the market. the mixture is left for 8-12 hours until it separates into two layers, which are the biodiesel upper layer and the glycerol lower layer. The two materials of different densities can be separated by a separating funnel. The biodiesel process is carried out after separation by pouring water at a temperature of 70 ºC to get rid of methanol and the catalyst. This process is repeated several times as needed. The biodiesel is dry by heating it at 110 ºC for 25 minutes.

Table 4-1 Biodiesel yields

Experimental Conditions	Run1	Run2
The temperature of reaction ºC	60	60
Time of reaction (min)	120	120
Palm olein oil (gram)	50	100
Methanol (gram)	11	20
Catalyst NaOH (gram)	0.375	0.75
Biodiesel (gram)	44.87	89.35
Glycerin (gram)	12.43	21.39

4.2.1 *Physico-Chemical Properties of the Biodiesel Fuel*

Table (4.2) shows the inferred fuel results. Kinematic viscosity is a measure of the friction of the internal fluid or flow resistance of oil that appears to oppose any dynamic change in the motion of the fluid. Kinematic viscosity is the key explanation of why biodiesel transesterifies fats and oils. Biodiesel's viscosity is about an order of magnitude smaller than that of the starting oil or fat. As the Kinematic viscosity of palm oil 35 cSt, and after the transesterification decreased to 4,681 cSt, biodiesel showed an increase in the Kinematic viscosity compare to fossil diesel that has 2.8 cSt [53]. Biodiesel showed a higher density than fossil diesel fuel, as biodiesel at 25 °C had a density of 0.8748 g/ml compared to fossil diesel fuel with a density of 0.84 g/ml at the same temperature [50]. The flashpoint is the temperature at which fuel can ignite when exposed to a heat source. It is important from the standpoint of safe handling, storage, and transportation. It is the amount of heating energy that a unit value of fuel releases through combustion. With increasing chain length, calorific value increases and with increasing unsaturation decreases, and it is important to estimate the fuel consumption, the lower fuel consumption, the higher the calorific value Palm oil has a calorific value of 36000 kJ/kg, and after the transesterification increased to 37000 kJ/kg less compared to fossil diesel fuel of 44500 kJ/kg. The high flash point is known to ensure more safety in handling and storage. palm has a value of 341 ºC and after transesterification, it is 181 degrees Celsius and it is higher than diesel (103 degrees Celsius) and therefore it is safe to store, compared to that of fossil diesel fuel, which has 78 °C [54]. These values are also verified according to International standards for biodiesel including ASTM D6751 (US), EN 14214 (Europe), and BIS (India) as well as other plant-oil-based biodiesel. These results showed clear agreement.

Table 4-2 Physical and chemical specifications of biodiesel and diesel fuel according to EN14214.[54][50][55]

No.	Name of test	Unite	Biodiesel	Standard values for biodiesel EN 14214	Diesel
1	Density @25 ºC	g/ml	0.8748	0.86-0.90	0.84
2	Kinematic viscosity @40 ºC	cSt	4.681	3.5-5	2.8
3	Flashpoint	ºC	181	≥ 120	78
4	Cetane number	-	53	> 51	45
5	Lower calorific heating value	kJ/kg	37000	-	39500

4.3 Repeatability of measurements

To ensure the repeatability of experimental results, every test has been repeated three times. The average value of the repeated tests was adopted in the analysis. Figures (4.1) and (4.2) show the repeatability of the test. Differences between the tests are reported to exist for the same conditions. The reason behind that was the instrumental errors, change in the ambient conditions, and human errors.

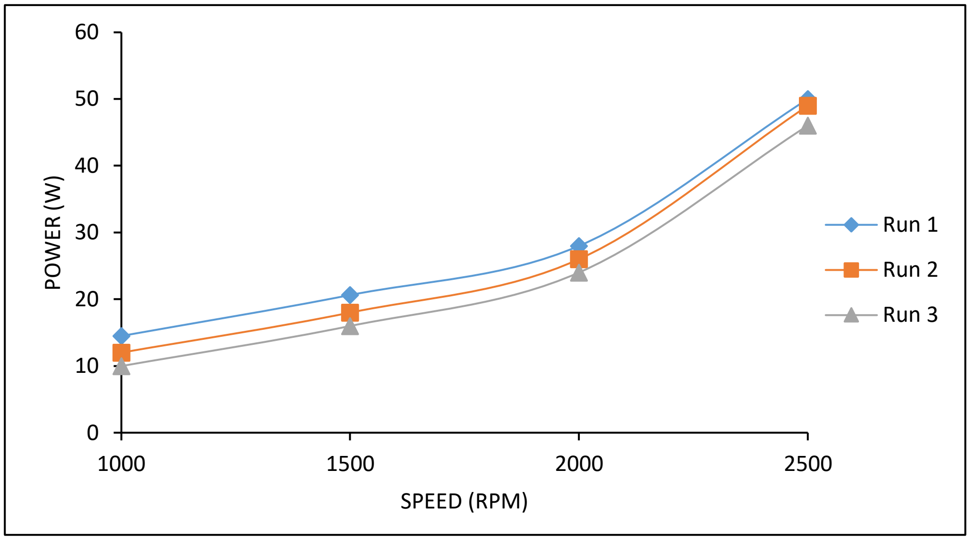


Figure 4-1 variation of power with engine speed at zero load

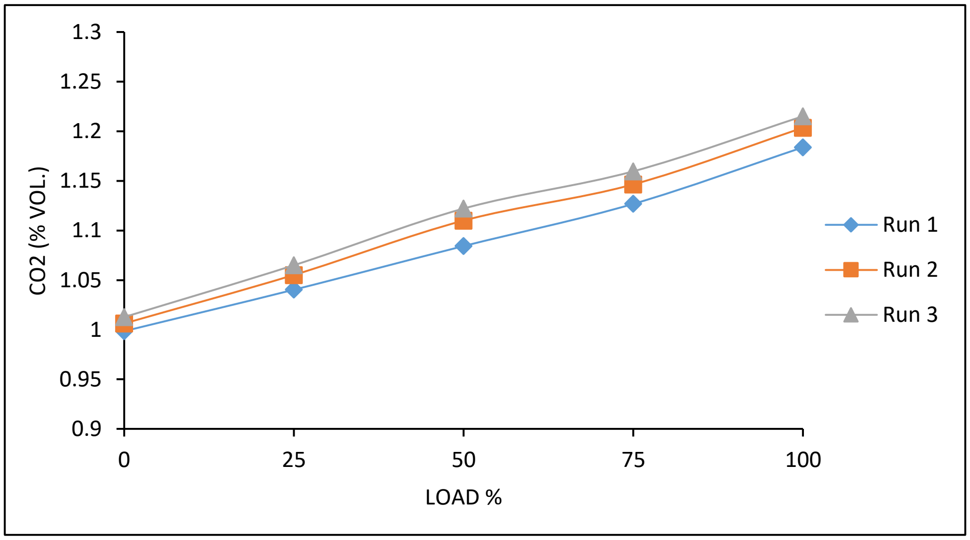


Figure 4-2 variation of CO2 and load at 2000 rpm

4.4 Comparison Study

To demonstrate the comparison of the experimental results a comparison performed between the results of **P. Shrivastava et al**. [24] the present work which it was obtained at 1500 rpm and engine load (0-100)% , and the result of the engine used is a 4-stroke, turbocharged inter-cooled CI engine with common rail direct injection system has been used for testing of diesel and blends of diesel/biodiesel. This work shows the comparison of the engine performance represented for brake thermal efficiency figure (4-3) , brake specific fuel consumption figure (4-4), and CO2 emission figure (4-5) respectively that it can prove good agreement in trend.

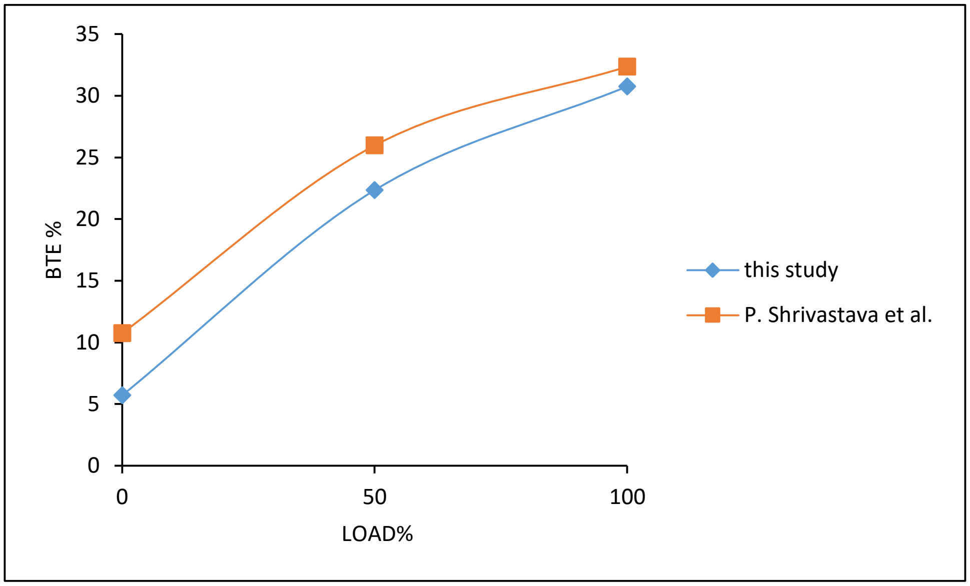


Figure 4-3 A comparison of brake thermal efficiency between results obtained in the present work and results of ref. [24]

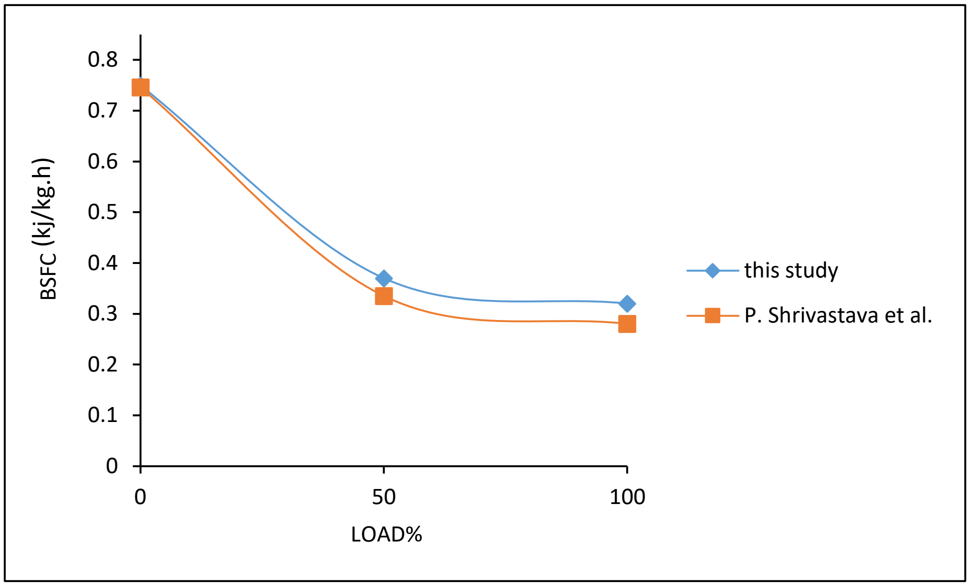


Figure 4-4 A comparison of brake specific fuel consumption between results obtained in the present work and results of ref. [24]

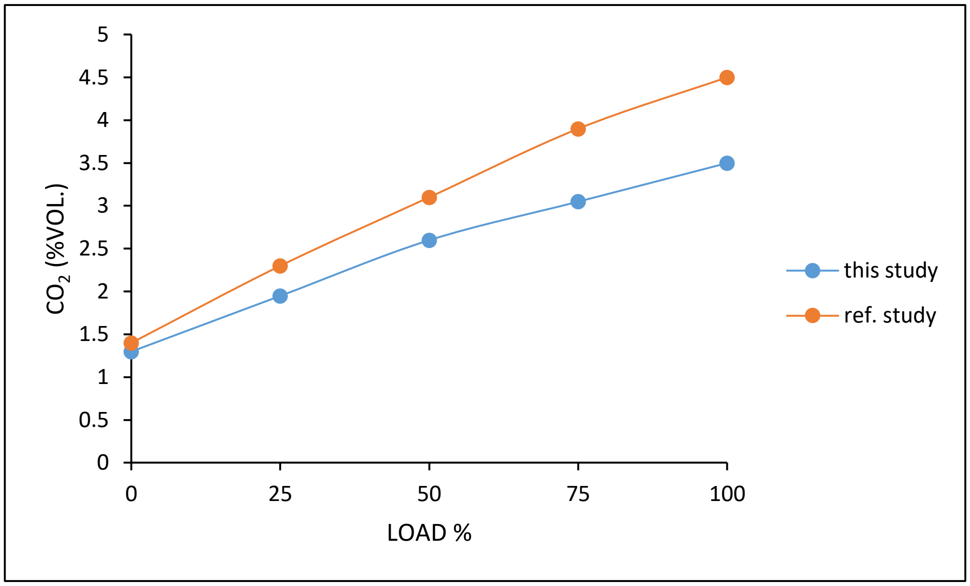


Figure 4-5 A comparison of CO_2 between results obtained in the present work and results of ref. [32]

4.5 Engine Performance Characteristics

4.5.1 *Brake Thermal Efficiency (BTHE)*

Several variables affect combustion in diesel engines, including fuel quality, cetane number, fuel optimization, fuel evaporation rate, combustion chamber design, injection timing, compression ratio, and pressure. By optimizing these factors, combustion can be improved, and thus the amount of fuel used and the rate of emissions generated by combustion can be reduced. One of the essential factors that affect diesel engine output and emissions is combustion efficiency and cetane number. The peak brake thermal efficiency in all cases is reached at 2500 rpm. Fig. (4.6) explains the brake thermal efficiency map for diesel and biodiesel fuel blends look based on engine load.

Fig. (4.6) A. shows that The thermal efficiency of B10, B20, B50, B70, and B100 fuel blends at 1000 rpm decreased by values of 0.52%, 0.94%, 1.26%, 1.53% and 1.55%, respectively, compared to fossil diesel fuels. Fig. (4.6) B. show that The thermal efficiency of B10, B20, B50, B70, and B100 fuel blends at 1500 rpm decreased by values of 0.89%, 1.53%, 2.23%, 2.84%, and 4.19%, respectively compared to fossil diesel fuels. Fig. (4.6) C. show that The thermal efficiency of B10, B20, B50, B70, and B100 fuel blends at 2000 rpm decreased by values of 0.26%, 0.96%, 1.61%, 1.9%, and 2.11%, respectively, compared to fossil diesel fuels. Fig. (4.6) D. show that The thermal efficiency of B10, B20, B50, B70, and B100 fuel blends at 2250 rpm decreased by values of 1.12%, 1.17 %, 2.54%, 2.8%, and 3.17%, respectively, compared to fossil diesel fuels. Fig. (4.6) E. show that The thermal efficiency of B10, B20, B50, B70, and B100 fuel blends at 2500 rpm decreased by values of 0.26%, 0.96 %, 2.6%, 3% and 3.6%, respectively, compared to fossil diesel fuels.

In reality, biodiesel has a lower calorific value than diesel fuel; however, because of its higher cetane number and oxygen content, biodiesel facilitates better combustion. Furthermore, whenever the masses pumped are compared, biodiesel fuel is injected in a larger mass from a fuel pump with the same volumetric capacity, and has a higher viscosity.

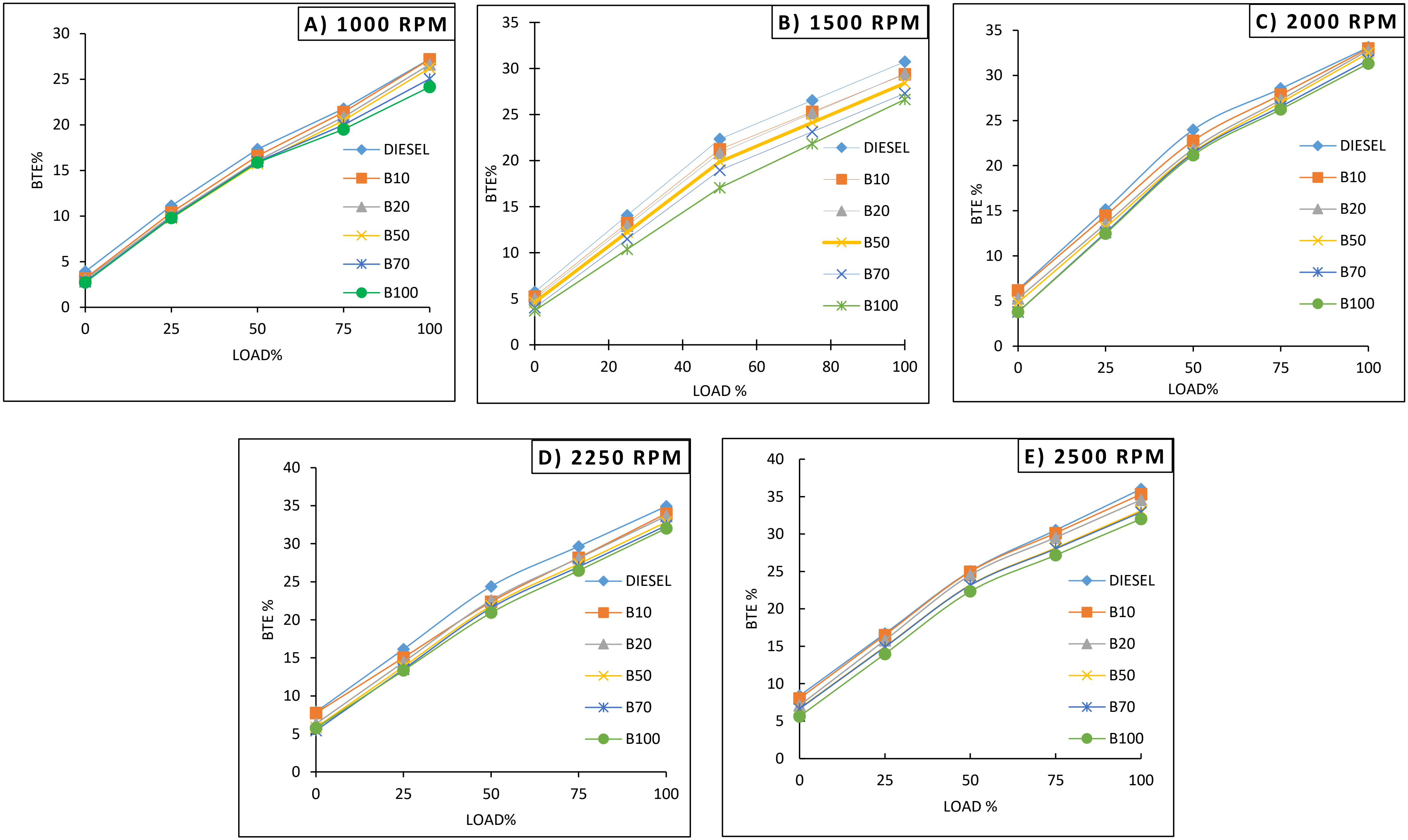


Figure 4-6 Brake thermal efficiency graphic according to engine load A) 1000 rpm, B)1500 rpm, C) 2000 rpm, D)2250 rpm, E) 2500 rpm

4.5.2 *Brake Specific Fuel Consumption*

Fig. (4.7) A shows the specific fuel consumption chart for biodiesel and diesel fuel blends depending on engine load. When comparing B10, B20, B50, B70, and B100 fuel blends at 1000 rpm, specific fuel consumption increased by 0.037 kg/kW-h, 0.047 kg/kW-h, 0.078 kg/kW-h, 0.131 kg/kW-h and 0.194 kg/kW-h (4.7) B. shows Brake Specific Fuel Consumption of B10, B20, B50, B70, and B100 fuel blends at 1500 rpm increased by 0.013 kg/kW-h, 0.065 kg/kW-h, 0.099 kg/kW-h, 0.115 kg/kW-h,, and 0.139 kg/kW-h, respectively, based on engine loads. Fig. (4.7) C. show Brake Specific Fuel Consumption of B10, B20, B50, B70, and B100 fuel blends at 2000 rpm increased by 0.012 kg/kW-h, 0.072 kg/kW-h, 0.099 kg/kW-h, 0.104 kg/kW-h,, and 0.13 kg/kW-h, respectively, based on engine loads. Fig. (4.7) D. show Brake Specific Fuel Consumption of B10, B20, B50, B70, and B100 fuel blends at 2250 rpm increased by 0.026 kg/kW-h, 0.036 kg/kW-h, 0.068 kg/kW-h, 0.131 kg/kW-h,, and 0.188 kg/kW-h, respectively, based on engine loads. . Fig. (4.7) E. show Brake Specific Fuel Consumption of B10, B20, B50, B70, and B100 fuel blends at 2500 rpm increased by 0.029 kg/kW-h, 0.033 kg/kW-h, 0.063 kg/kW-h, 0.082 kg/kW-h,, and 0.121 kg/kW-h, respectively, based on engine loads. The fuel consumption factor is affected by the viscosity, density, and lower calorific value of the injected fuel. Since biodiesel has a lower calorific value than diesel fuel, more fuel is pumped from the fuel pump to achieve the same power output as diesel fuel, increasing specific fuel consumption. The high viscosity makes the air-fuel mixture uneven, which leads to poor combustion of the fuel. The high density leads to a larger amount of fuel entering the combustion chamber for the same volume, thus consuming more fuel.

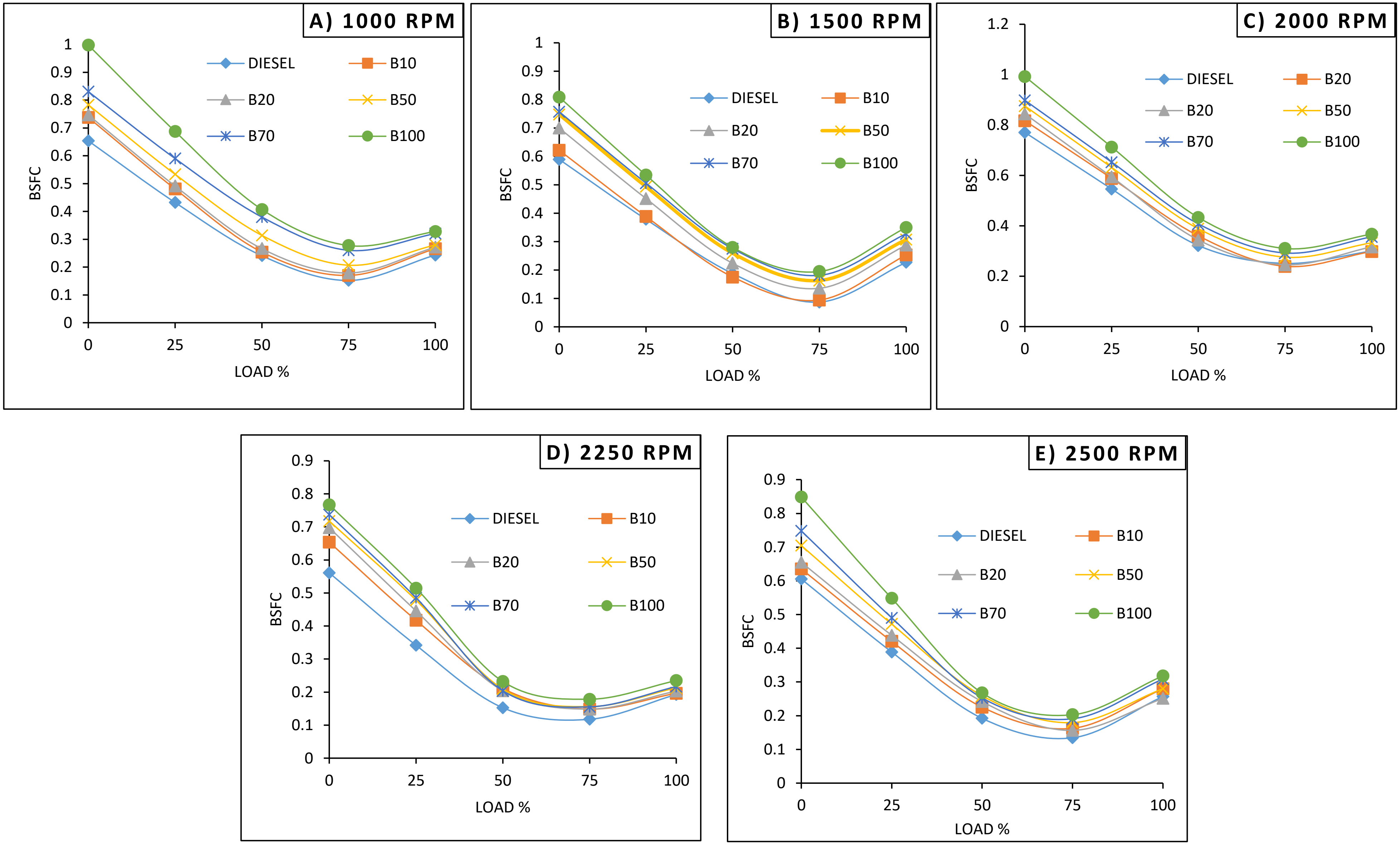


Figure 4-7 Brake Specific Fuel Consumption graphic according to engine load A) 1000 rpm, B)1500 rpm, C) 2000 rpm, D)2250 rpm, E) 2500 rpm

4.5.3 *Brake Power*

At higher engine loads, the engine's braking power is comparatively high since the increased combustion temperature contributes to more full combustion during the higher load.

Fig. (4.8) A. shows Brake power of B10, B20, B50, B70, and B100 fuel blends at 1000 rpm decreased by 0.013 kW, 0.018 kW, 0.024 kW, 0.039 kW, and 0.045kW, respectively, based on engine loads. Fig. (4.8) B. shows Brake power of B10, B20, B50, B70, and B100 fuel blends at 1500 rpm decreased by 0.014 kW, 0.017 kW, 0.025 kW, 0.023 kW, and 0.031 kW, respectively, based on engine loads. Fig. (4.8) C. shows Brake power of B10, B20, B50, B70, and B100 fuel blends at 2000 rpm decreased by 0.014 kW, 0.017 kW, 0.025 kW, 0.023 kW, and 0.031 kW, respectively, based on engine loads. Fig. (4.8) D. shows Brake power of B10, B20, B50, B70, and B100 fuel blends at 2250 rpm decreased by 0.023 kW, 0.033 kW, 0.034 kW, 0.43 kW, and 0.061 kW, respectively, based on engine loads. Fig. (4.8) E. shows Brake power of B10, B20, B50, B70, and B100 fuel blends at 2500 rpm decreased by 0.009 kW, 0.019 kW, 0.022 kW, 0.023 kW, and 0.034 kW, respectively, based on engine loads.

Apart from that, at different loads, pure diesel controlled the output brake power. The viscosity and density of fuels play a key role in the atomization process and can slow down the fuel-air mixing rate, resulting in poor fuel combustion and reduced brake power.

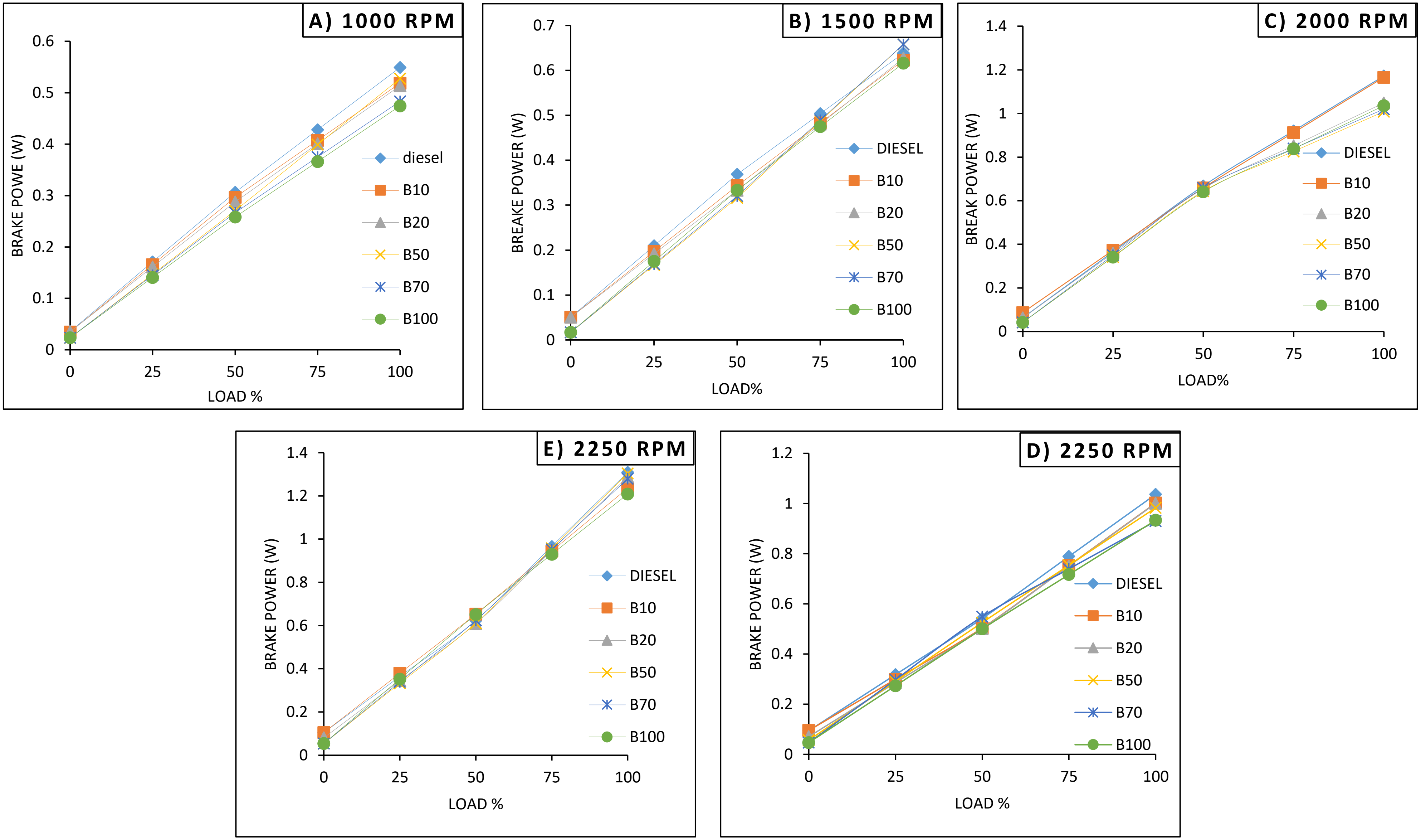


Figure 4-8 Brake power graphic according to engine load A) 1000 rpm, B)1500 rpm, C) 2000 rpm, D)2250 rpm, E) 2500 rpm

4.5.4 *Volumetric efficiency*

The volumetric efficiency of a compressor cylinder refers to how well it compresses the gas. It's the ratio of the amount of gas supplied to the piston displacement, adjusted for suction temperature and pressure. By far the most significant impact on volumetric performance is re-expansion. The engine's inlet temperature and pressure have a direct impact on volumetric performance. The differences in volumetric efficiency for various tested fuels under various loading conditions are shown in Fig. (4-9). the tested fuels had similar inlet conditions, and all of the tested fuels had marginal volumetric efficiency decreases as compared to diesel.

Fig. (4.9) A. shows volumetric efficiency of B10, B20, B50, B70, and B100 fuel blends at 1000 rpm decreased by 0.808%, 1.24 %, 2.3 %, 3.31 %, and 4.29 %, respectively, compare to diesel based on engine loads. Fig. (4.9) B. shows Volumetric efficiency of B10, B20, B50, B70, and B100 fuel blends at 1500 rpm decreased by 0.76 %, 1.41 %, 3.08 %, 4.64 %, and 6 %, respectively, compare to diesel based on engine loads. Fig. (4.9) C shows Volumetric efficiency of B10, B20, B50, B70, and B100 fuel blends at 2000 rpm decreased by 0.73 %, 1.43 %, 2.97 %, 3.9 %, and 4.83 %, respectively, compare to diesel based on engine loads. Fig. (4.9) D. show Volumetric efficiency of B10, B20, B50, B70, and B100 fuel blends at 2250 rpm decreased by 0.93 %, 1.67 %, 2.53 %, 3.99 %, and 5.02 %, respectively, compare to diesel based on engine loads. Fig. (4.9) E. show Volumetric efficiency of B10, B20, B50, B70, and B100 fuel blends at 2500 rpm decreased by 0.8 %, 1.45 %, 2.5 %, 3.63 %, and 5.22 %, respectively, compare to diesel based on engine loads.

The main reason for the low volumetric efficiency of biodiesel is the high biodiesel combustion chamber temperature, which leads to an increase in pressure inside the combustion chamber and therefore less air in the combustion chamber

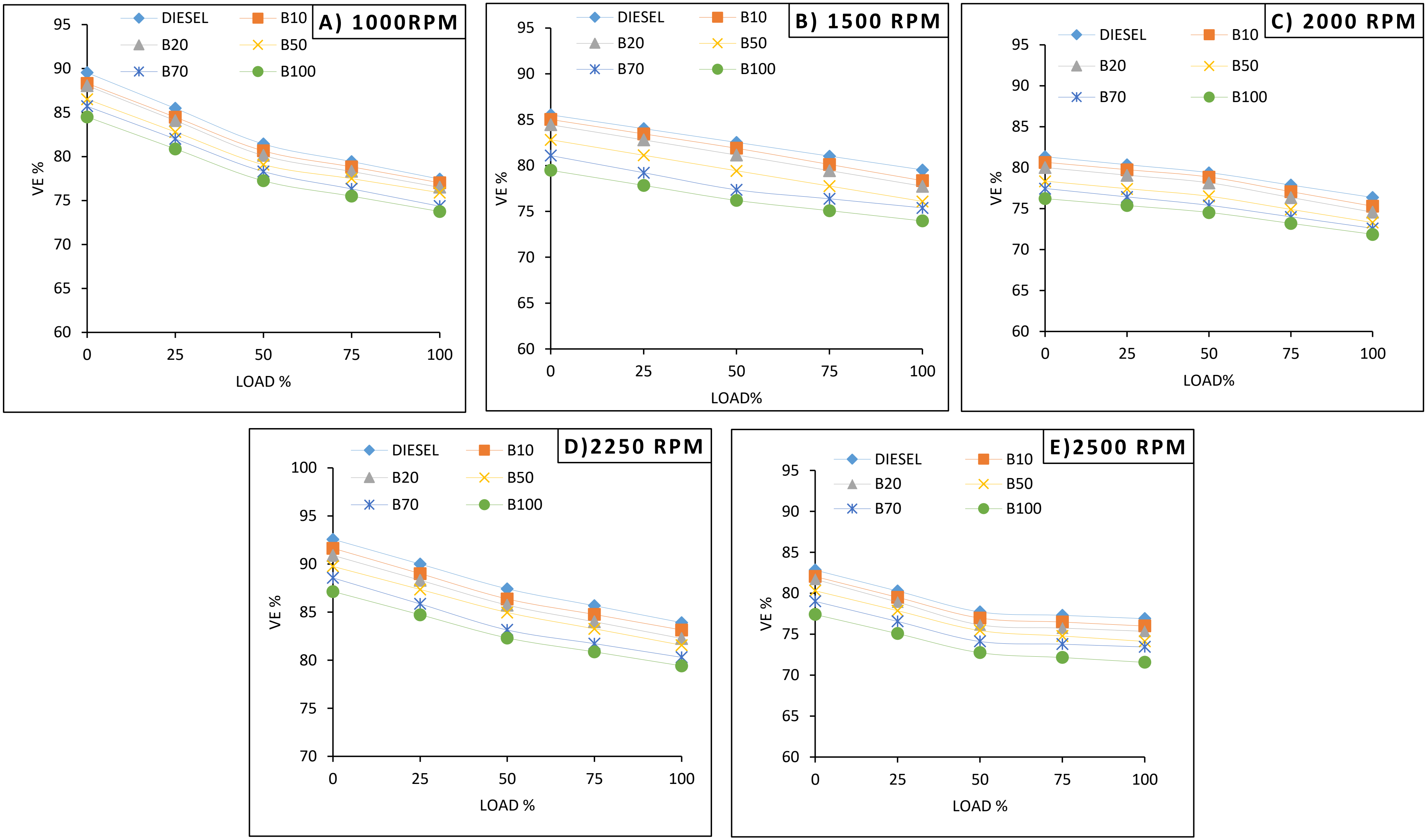


Figure 4-9 volumetric efficiency graphic according to engine load A) 1000 rpm, B)1500 rpm, C) 2000 rpm, D)2250 rpm, E) 2500 rpm

4.6 Engine exhaust emissions

4.6.1 *Hydrocarbon (HC)*

Unburned hydrocarbon (HC) is another critical parameter in evaluating the engine's emission activity. As can be seen from graph Fig. (4.10), neat biodiesel (B100) produces significantly less HC than neat diesel. The variations in HC emissions from diesel and biodiesel dependent on engine load are depicted in Fig. (4.10) A. B10, B20, B50, B70, and B100 blends at 1000 rpm have produced lower HC emissions in average by 1 ppm, 2ppm, 4 ppm, 5ppm, and 6ppm, respectively compared to the HC emission of diesel. Fig. (4.10) B. B10, B20, B50, B70, and B100 blends at 1500 rpm have produced lower HC emissions on average by 3 ppm, 6 ppm, 12 ppm, 18 ppm, and 27 ppm, respectively compared to the HC emission of diesel. Fig. (4.10) C. B10, B20, B50, B70, and B100 blends at 2000 rpm have produced lower HC emissions on average by 3 ppm, 6 ppm, 11 ppm, 16 ppm, and 21 ppm, respectively compared to the HC emission of diesel. Fig. (4.10) D. B10, B20, B50, B70, and B100 blends at 2250 rpm have produced lower HC emissions on average by 1 ppm, 5 ppm, 9 ppm, 13 ppm, and 17 ppm, respectively compared to the HC emission of diesel. Fig. (4.10) E. B10, B20, B50, B70, and B100 blends at 2500 rpm have produced lower HC emissions on average by 2 ppm, 3 ppm, 7 ppm, 11 ppm, and 16 ppm, respectively compared to the HC emission of diesel.

High cetane number in biodiesel may reduce the HC emission. The oxygen content of biodiesel ensured sufficient oxidation in the rich air-fuel mixture areas, which is the main reason why HC emissions decreased when biodiesel and its blends were used. Diesel engines' high compression ratio resulted in higher exhaust temperatures. As a result, it's possible that the chamber's unburned hydrocarbons were oxidized towards the exhaust outlet.

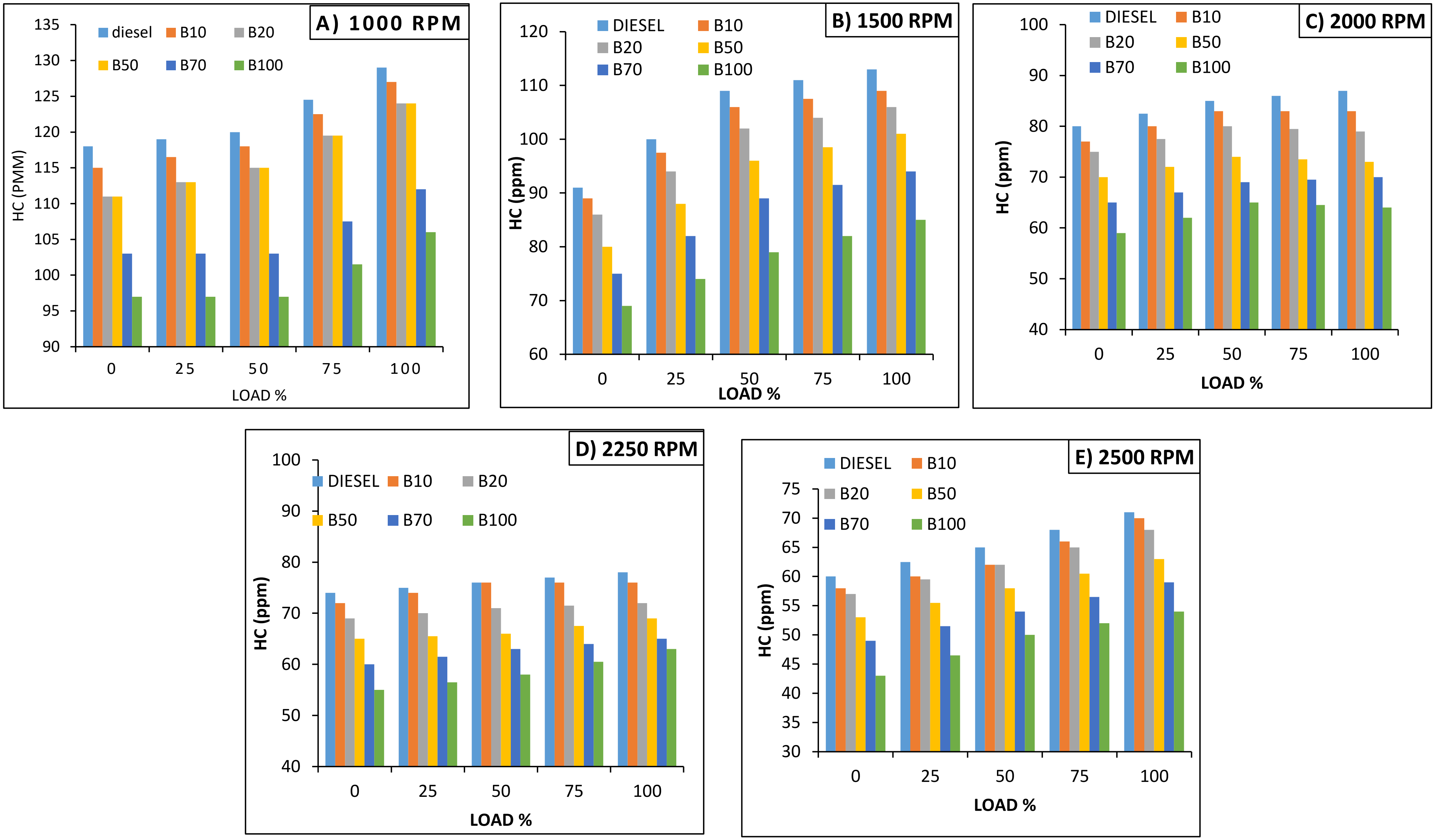


Figure 4-10 HC graphic according to engine load A) 1000 rpm, B)1500 rpm, C) 2000 rpm, D)2250 rpm, E) 2500 rpm

4.6.2 *Nitrogen oxides (NO_X)*

When nitrogen in the air reacts with oxygen at high temperatures in internal combustion engines, nitrogen oxides (NOx) are formed. Fig. (4.11) depicts NOx shifts for diesel and biodiesel based on engine loads.

Based on the engine loads, fig. (4.11) A. shows the NOx emissions of B10, B20, B50, B70, and B100 fuels blends at 1000 rpm increased by an average of 65 ppm, 107 ppm, 269 ppm, 289 ppm, and 332 ppm respectively compared to diesel. Fig. (4.11) B. show the NOx emissions of B10, B20, B50, B70 and B100 fuels blends at 1500 rpm increased by an average of 41 ppm, 105 ppm, 137 ppm, 239 ppm, and 312 ppm respectively compared to diesel. Fig. (4.11) C. show the NOx emissions of B10, B20, B50, B70 and B100 fuels blends at 2000 rpm increased by an average of 55 ppm, 167 ppm, 215 ppm, 261 ppm, and 336 ppm respectively compared to diesel. Fig. (4.11) D. show the NOx emissions of B10, B20, B50, B70 and B100 fuels blends at 2250 rpm increased by an average of 19 ppm, 173 ppm, 185 ppm, 285 ppm, and 321 ppm respectively compared to diesel. Fig. (4.11) E. shows the NOx emissions of B10, B20, B50, B70, and B100 fuels blends at 2500 rpm increased by an average of 19 ppm, 54 ppm, 221 ppm, 273 ppm, and 317 ppm respectively compared to diesel.

The higher specific fuel consumption with all biodiesel blends as compared to diesel fuel is due to an increased combustion rate caused by sufficient oxidation in fuel-rich regions due to biodiesel's oxygen content. As a result of the higher NO_X emissions caused by the increased temperature inside the chamber and high adiabatic film temperature.

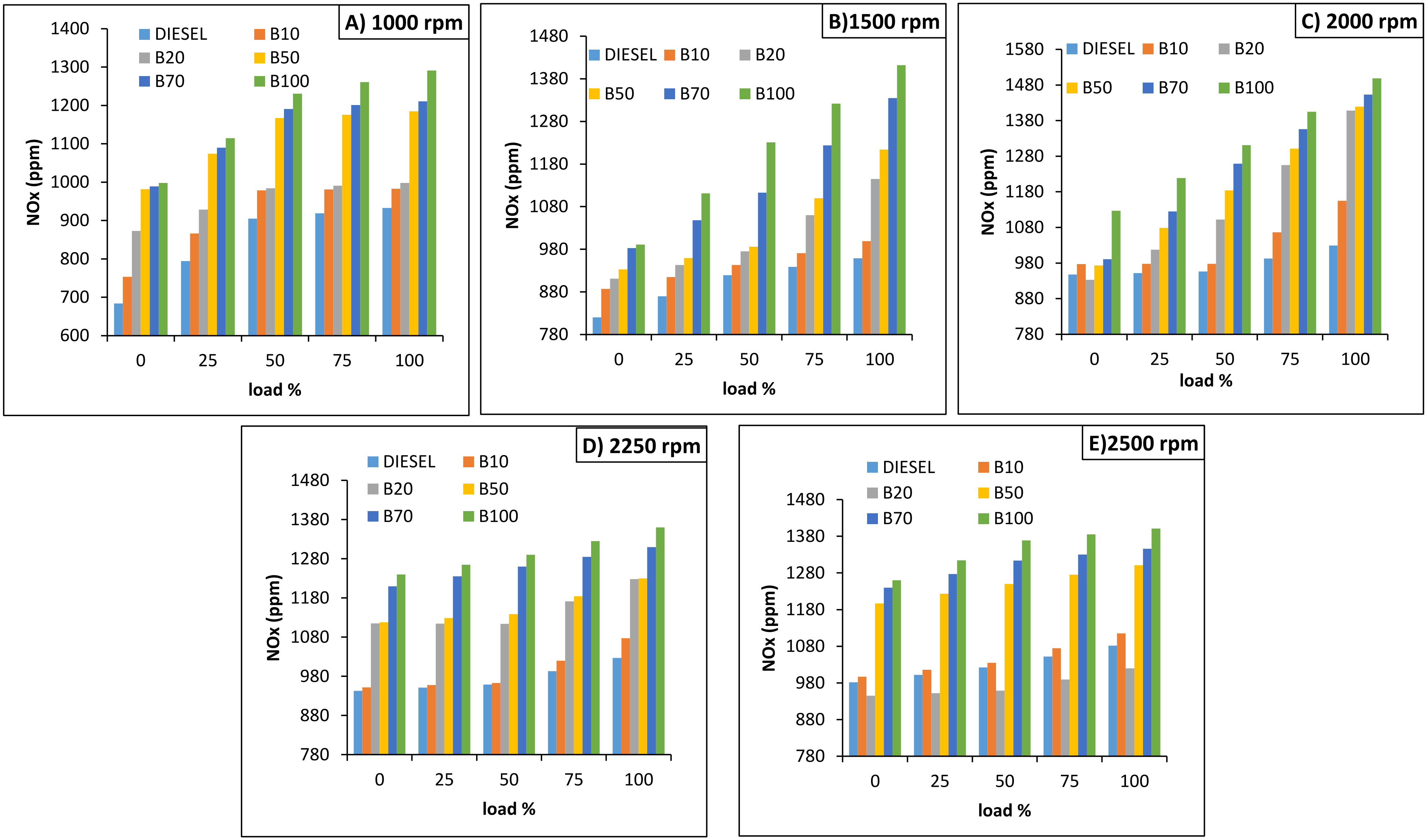


Figure 4-11 Nitrogen oxides (NO_X) graphic according to engine load. A) 1000 rpm, B)1500 rpm, C) 2000 rpm, D)2250 rpm, E) 2500 rpm

4.6.3 *Carbon monoxide (CO)*

Carbon monoxide, which is made up of one carbon atom and one oxygen atom, is a volatile gas that can affect the atmosphere, so its emissions from dual-fuel engines should be kept to a minimum.

Fig. (4.12) depicts the difference in CO emissions as a function of engine load. Fig. (4.12) A. CO emissions based on the engine load, for B10, B20, B50, B70, and B100 fuel blends at 1000 rpm the CO emissions decreased by 0.018 %vol., 0.024 %vol, 0.042 %vol, 0.068 % vol and 0.072 % vol, compare to diesel respectively. Fig. (4.12) B. show CO emissions based on the engine load, for B10, B20, B50, B70, and B100 fuel blends at 1500 rpm the CO emissions decreased by 0.008 %vol., 0.02 %vol, 0.03 %vol, 0.054 % vol, and 0.068 % vol, compare to diesel respectively. Fig. (4.12) C. show CO emissions Based on the engine load, for B10, B20, B50, B70, and B100 fuel blends at 2000 rpm the CO emissions decreased by 0.014 %vol., 0.02 %vol, 0.028 %vol, 0.052 % vol, and 0.066 % vol, compare to diesel respectively. Fig. (4.12) D. show CO emissions Based on the engine load, for B10, B20, B50, B70, and B100 fuel blends at 2250 rpm the CO emissions decreased by 0.012 %vol., 0.024 %vol, 0.032 %vol, 0.052 % vol, and 0.068 % vol, compare to diesel respectively. . Fig. (4.12) E. show CO emissions Based on the engine load, for B10, B20, B50, B70 and B100 fuel blends at 2000 rpm the CO emissions decreased by 0.016 %vol., 0.026 %vol, 0.032 %vol, 0.052 % vol and 0.068 % vol, compare to diesel respectively.

Incomplete combustion has been one of the primary causes of CO creation. Since diesel engines work with an enormous amount of air, CO emissions are typically low. Biodiesel has a higher cetane number than diesel fuel, as well as the oxygen content in it, raised combustion, and reduced CO emissions.

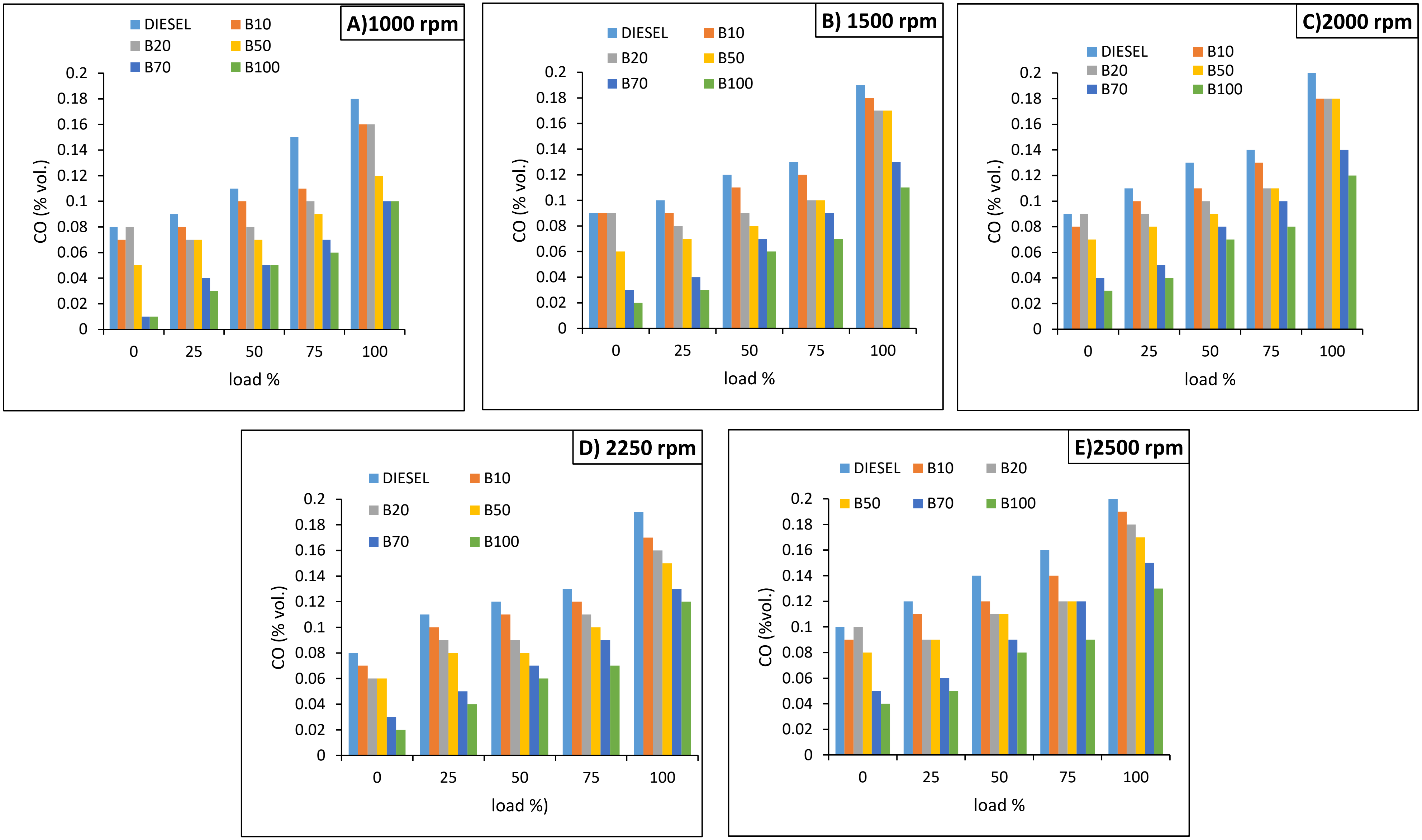


Figure 4-12 Carbon monoxide graphic according to engine load. A) 1000 rpm, B)1500 rpm, C) 2000 rpm, D)2250 rpm, E) 2500 rpm

4.6.4 *Carbon dioxide (CO_2)*

Total combustion is indicated by the CO_2 emission factor. Figure (4-13) shows the difference in carbon dioxide emissions as a function of engine load and fuel blend. Fig. (4.13) A. show the CO_2 emissions of B10, B20, B50, B70 and B100 fuel blends at 1000 rpm increased by an average of 0.3 % vol., 0.3 % vol., 0.9 %vol., 1.5 %vol. and 1.8 %vol. respectively, compared to that of diesel fuel blend based on the engine load. Fig. (4.13) B. show the CO_2 emissions of B10, B20, B50, B70 and B100 fuel blends at 1500 rpm increased by an average of 0.2 % vol., 0.4 % vol., 0.5 %vol., 0.8 %vol. and 1.4 %vol. respectively, compared to that of diesel fuel blend based on the engine load. Fig. (4.13) C. show the CO_2 emissions of B10, B20, B50, B70 and B100 fuel blends at 2000 rpm increased by an average of 0.3 % vol., 0.4 % vol., 0.43 %vol., 0.7 %vol. and 1.1 %vol. respectively, compared to that of diesel fuel blend based on the engine load. Fig. (4.13) D. show the CO_2 emissions of B10, B20, B50, B70 and B100 fuel blends at 2250 rpm increased by an average of 0.2 % vol., 0.3 % vol., 0.6 %vol., 0.8 %vol. and 1.2 %vol. respectively, compared to that of diesel fuel blend based on the engine load. Fig. (4.13) E. show the CO2 emissions of B10, B20, B50, B70 and B100 fuel blends at 1500 rpm increased by an average of 0.2 % vol., 0.4 % vol., 0.5 %vol., 0.8 %vol. and 1 %vol. respectively, compared to that of diesel fuel blend based on the engine load.

Since biodiesel has a higher oxygen content, CO_2 emissions rise, potentially leading to full combustion. CO_2 emissions from renewable fuels can be used by trees and plants to keep CO_2 levels in the atmosphere stable.

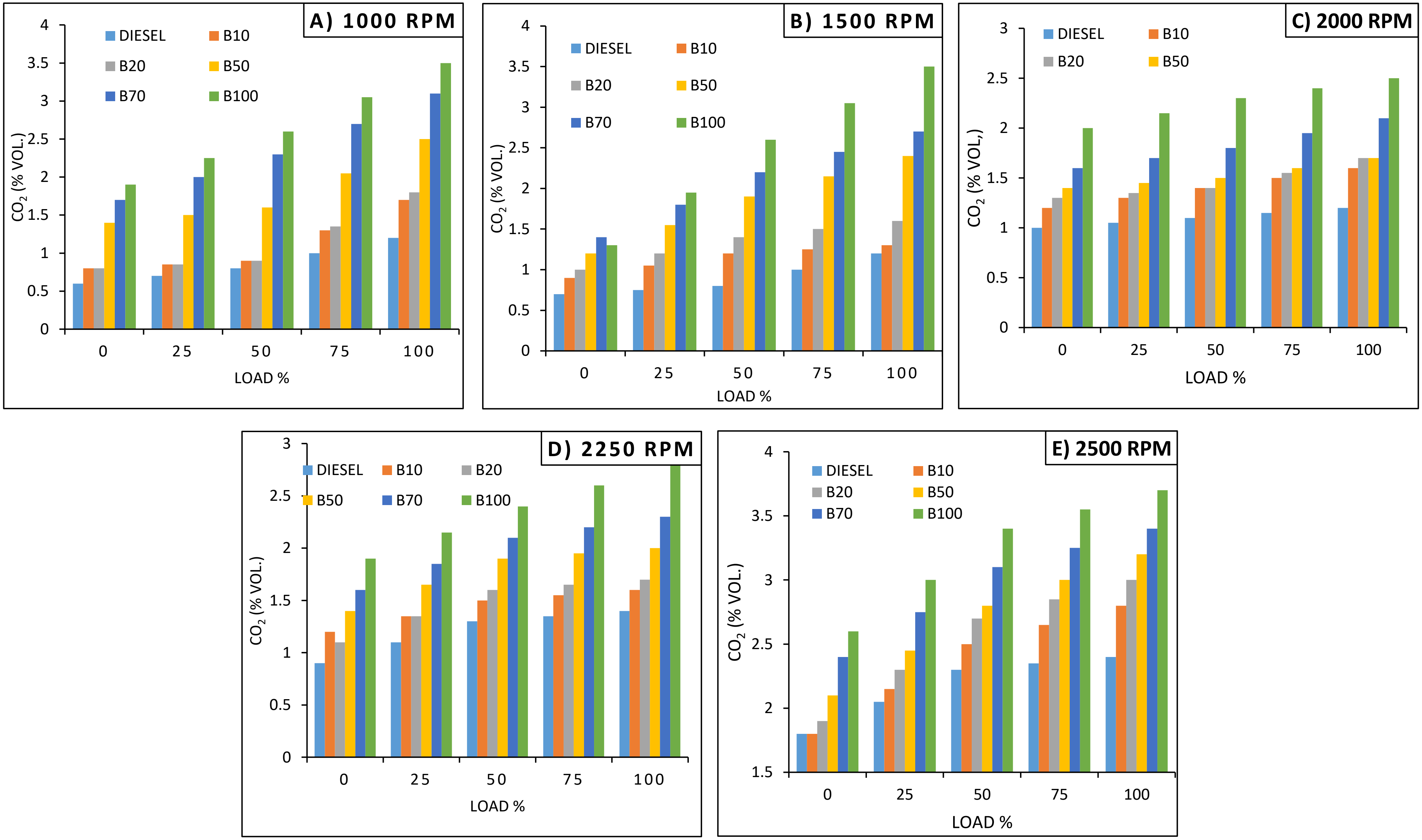


Figure 4-13 Carbon dioxide graphic according to engine load A) 1000 rpm, B)1500 rpm, C) 2000 rpm, D)2250 rpm, E) 2500 rpm.

4.6.5 *Exhaust Gas Temperature*

The temperature of the exhaust gas offers information about the combustion process's efficiency. Fig. (4.14) depicts the variations in exhaust gas temperature (EGT) as a function of engine load for various blends. For all of the fuels tested, EGT increased as the engine load increased. The EGT of diesel fuel was found to be higher than that of other fuels. This will result in continuous fuel combustion until the combustion process is completed, releasing an increasing amount of heat.

Fig. (4.14) A. at 1000 rpm, the EGTs and at full load were recorded to be about 138 °C, 137 °C, 135 °C, 135 °C, and 132 °C, respectively for diesel, B10, B20, B50, B70, and B100 compared to that of 130 °C for mineral biodiesel. Fig. (4.14) B at 1500 rpm, the EGTs and at full load were recorded to be about 161 °C, 160 °C, 159 °C, 158 °C, and 156 °C, respectively for diesel, B10, B20, B50, B70, and B100 compared to that of 154°C for mineral biodiesel. Fig. (4.14) C. at 2000 rpm, the EGTs and at full load were recorded to be about 183 °C, 182 °C, 182 °C, 180 °C, and 179 °C, respectively for diesel, B10, B20, B50, B70, and B100 compared to that of 177 °C for mineral biodiesel. Fig. (4.14) D °C, 189 °C, 187 °C, and 185 °C, respectively for diesel, B10, B20, B50, B70, and B100 compared to that of 184 °C for mineral biodiesel. Fig. (4.14) E. at 2500 rpm, the EGTs and at full load were recorded to be about 227 °C, 226 °C, 224 °C, 223 °C, and 223 °C, respectively for diesel, B10, B20, B50, B70, and B100 compared to that of 220 °C for mineral biodiesel.

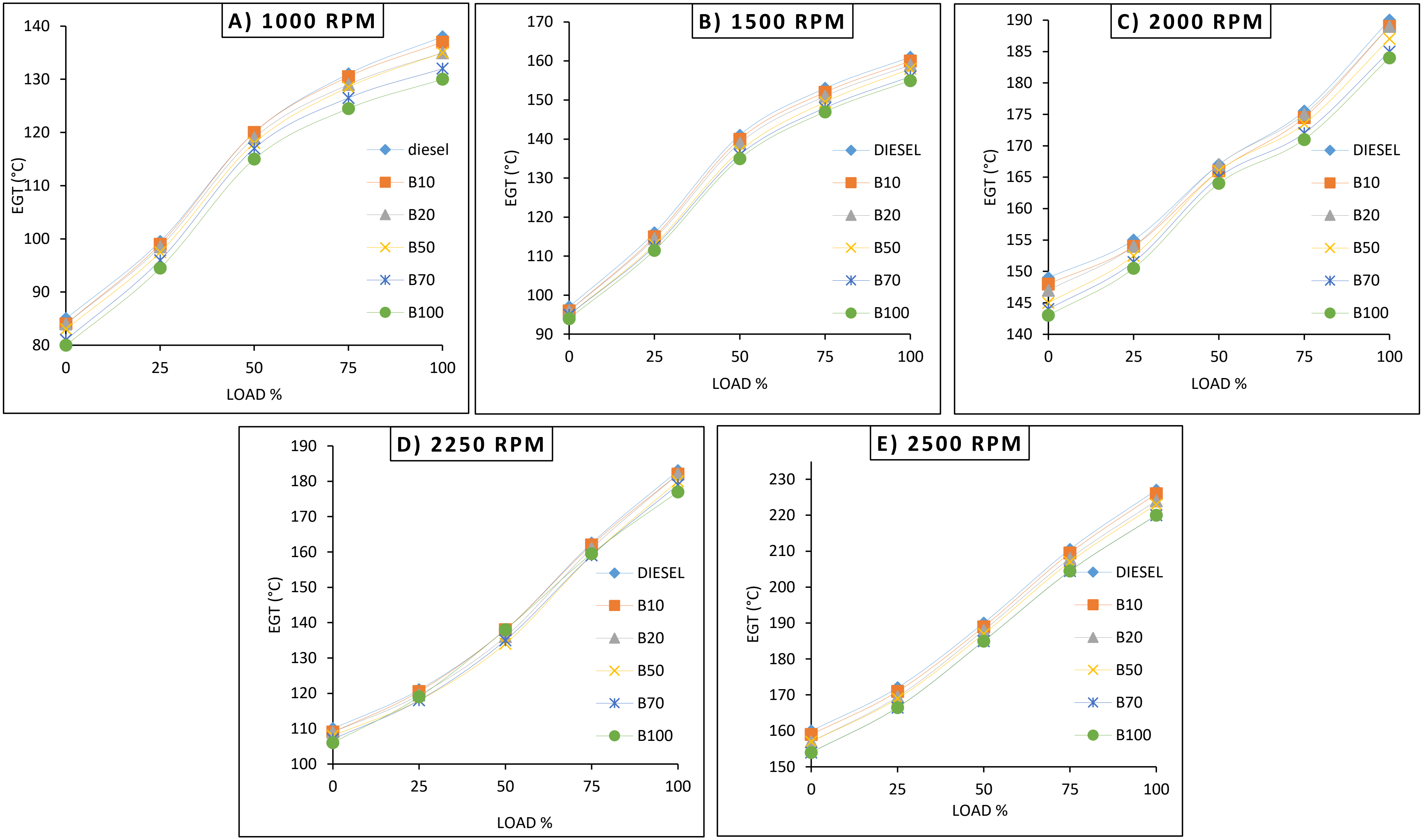


Figure 4-14 exhaust gas temperature graphic according to engine load A) 1000 rpm, B)1500 rpm, C) 2000 rpm, D)2250 rpm, E) 2500 rpm

4.7 Economic Analysis

Biodiesel prices are less cost than that undertaken for diesel. The price of biodiesel (0.372 USD per Liter) and the price of diesel fuel (0.375 USD per Liter) as shown in table (4-3) based on the Iraqi Ministry of Oil prices for the year 2021. Which reveals that biodiesel has decrease priced around 0.8% than diesel fuel as shown in figure (4-15).

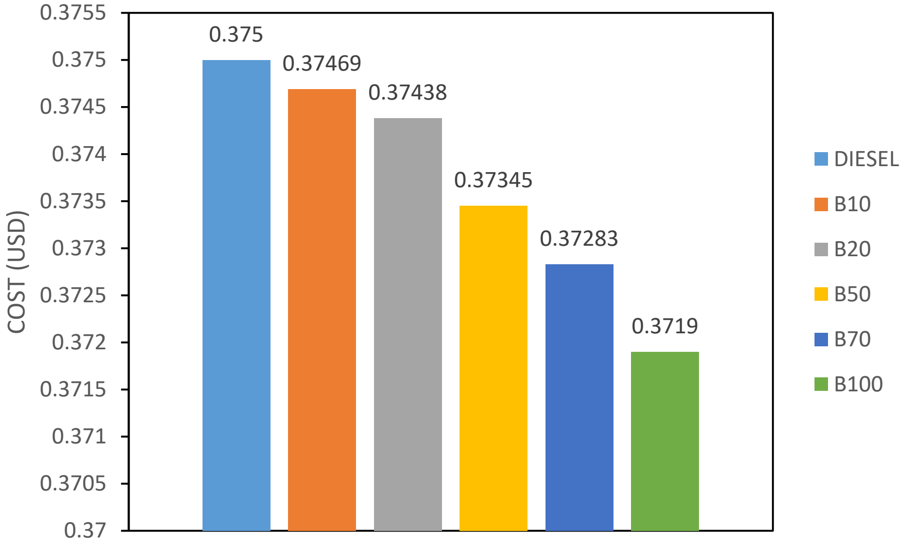


Figure 4-15 Comparing the cost of producing one liter of biodiesel with one liter of diesel

Table 4-3 cost of raw materials used to produce one liter of biodiesel.

type of fuel	Methanol	H_2SO_4	NaOH	Vegetable oil	total cost
Biodiesel	0.081	0.0069	0.014	0.27	0.3719
B70	0.0567	0.00483	0.0098	0.189	0.37283
B50	0.0405	0.00345	0.007	0.135	0.37345
B20	0.0162	0.00138	0.0028	0.054	0.37438
B10	0.0081	0.00069	0.0014	0.027	0.37469
Diesel	-	-	-	-	0.375

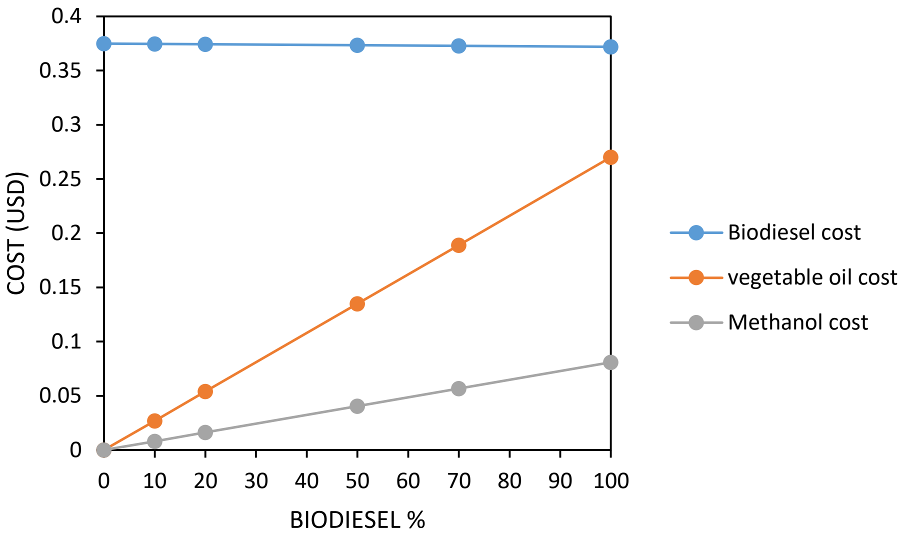


Figure 4-16 biodiesel cost and feedstock cost per liter**.**

Fig. (4.16) show comparing the cost of producing one liter of biodiesel with one liter of diesel. The low cost of biodiesel can be seen. The cost decrease by 0.8%, 0.49%, 0.41%, 0.16 % and 0.08% for B100, B70, B50, B20, and B10, respectively, compared to diesel fuel.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In this study, performance and emission characteristic of biodiesel fuel, binary fuel blend and ternary fuel blend of biodiesel with diesel were experimentally studied in a single-cylinder CI engine without any modifications at various engine speeds (1000 – 2500 rpm) with engine load (0, 25, 50, 75, 100) %. The following conclusions of this study are drawn based on the results of the study:

1. Biodiesel can be used directly and without modification in the internal combustion engine as an alternative fuel source to fossil diesel
2. The brake thermal efficiency of B10, B20, B50, B70, and B100 fuel blends decreased by values of 0.76%, 1.53%, 2.56%, 3% and 3.66%, respectively, compared to fossil diesel fuels.
3. The brake specific fuel consumption increased by 15% compared to fossil diesel fuels.
4. Volumetric efficiency shows negative behavior with the increase in the engine load and alternative fuel blending or dedicated where it decreases.
5. The brake power decreases with an increase in the percentage of biodiesel in fuel mixtures compared to fossil diesel fuels
6. There is a significant reduction of exhaust gas emissions in (CO and HC) with using biodiesel fuel 84.1 % and 17% respectively, compared to fossil diesel fuels
7. The exhaust gas temperature increases with increase of the engine load. For the same engine load and speed, it is found that exhaust gas temperatures for diesel fuel is higher at all the engine loads compared to

biodesel fuel. The maximum exhaust gas temperature reported was 227C° for B10 fuel for engine speed equals to 2500.

8. This type of biodesel fuel can be considered as environmentally friendly.

5.2 Recommendations for Future Work

Some recommendations for future research works:

1- Studying the effect of using heterogeneous catalysts on transesterification.

2- Experimental analysis of a single cylinder, four stroke VCR (Variable compression ratio) using biodiesel blends.

3- Study the effect of biodiesel on air/fuel ratio.

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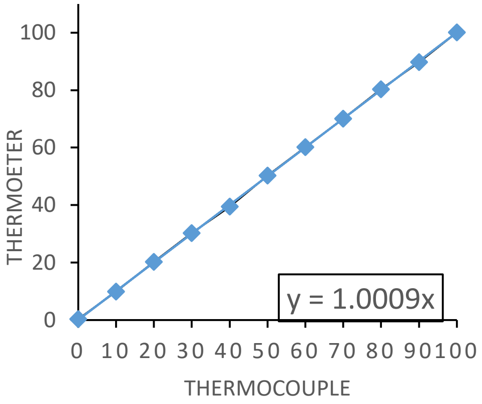
Appendix A : Calibration

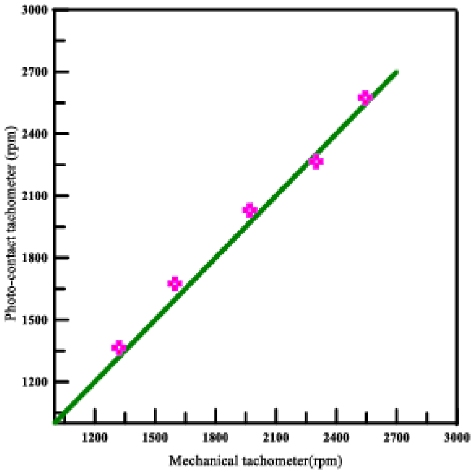
Exhaust gas temperature thermocouple

The error percentage is 1%.



Mechanical Contact Hand-Tachometers

The error percentage is 2.5%.



Appendix B: List of publications

1- Accept of the research (**Biodiesel Production From Palm Olein Oil Using Acid-catalyzed Esterification**)

2nd International Conference on Engineering and Science (ICES2021)
26 -27 MAY 2021
AL-SAMAWAH, IRAQ

Final Acceptance Letter

Manuscript Number: ICES2021-111 **Decision ID : FAL-ICES-004**

Dear Mohammed Hussein

Co-Authors : Hyder H. Balla and Mudhaffar S. Al-Zuhairy

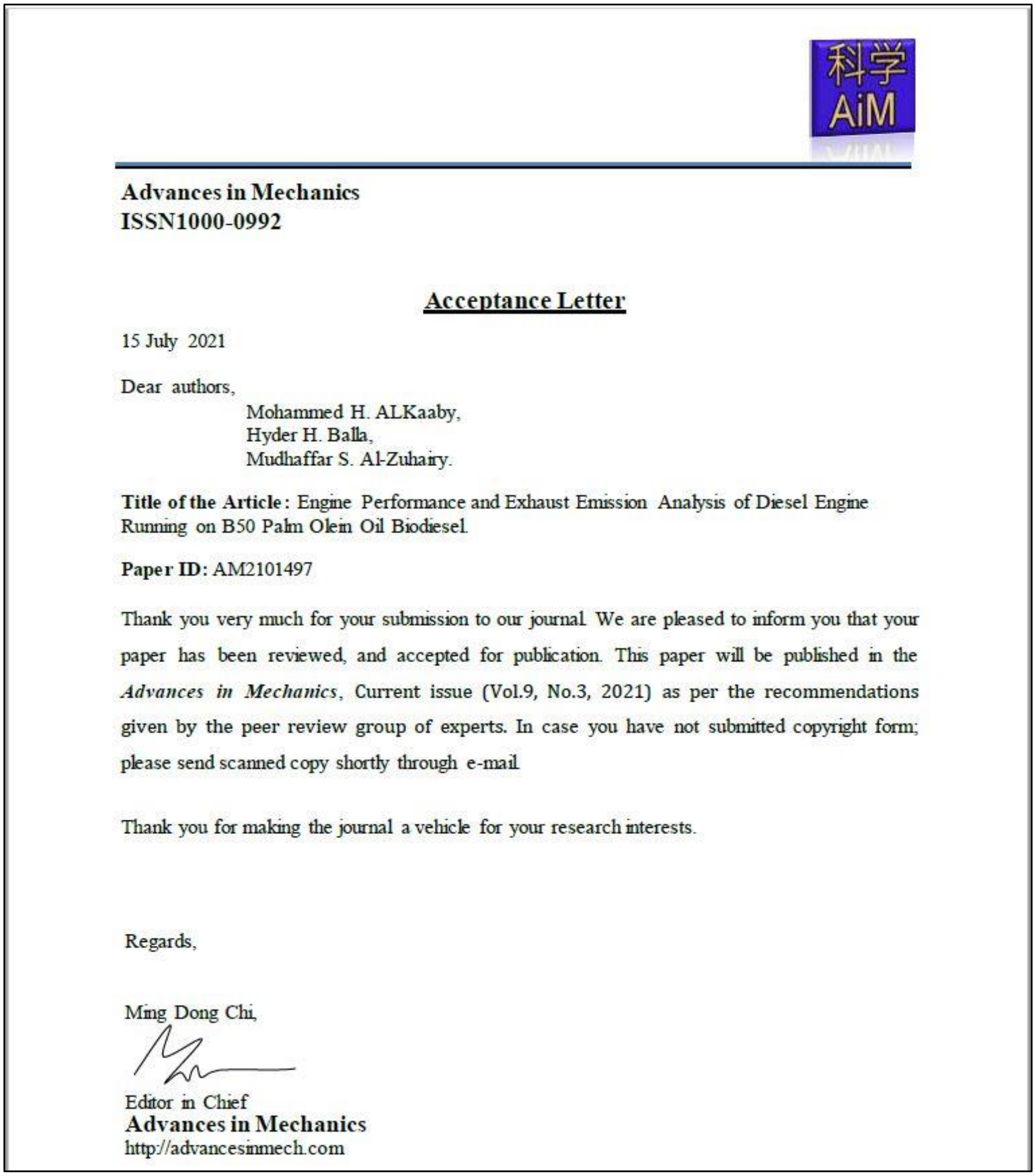
Congratulations!

It's a great pleasure to inform you that, after the peer review process, your manuscript entitled

(Biodiesel Production From Palm Olein Oil Using Acid-Catalyzed Esterification)

Has been ACCEPTED for participating in the 2nd **International Conference on Engineering and science**, and considered for publication in (**AIP Conference proceeding).**

2- Accepted and published (**Engine Performance and Exhaust Emission Analysis of Diesel Engine Running on B50 Palm Olein Oil Biodiesel**)



科学
AiM

Advances in Mechanics
ISSN1000-0992

Acceptance Letter

15 July 2021

Dear authors,
Mohammed H. ALKaaby,
Hyder H. Balla,
Mudhaffar S. Al-Zuhairy.

Title of the Article: Engine Performance and Exhaust Emission Analysis of Diesel Engine Running on B50 Palm Olein Oil Biodiesel.

Paper ID: AM2101497

Thank you very much for your submission to our journal. We are pleased to inform you that your paper has been reviewed, and accepted for publication. This paper will be published in the *Advances in Mechanics*, Current issue (Vol.9, No.3, 2021) as per the recommendations given by the peer review group of experts. In case you have not submitted copyright form; please send scanned copy shortly through e-mail.

Thank you for making the journal a vehicle for your research interests.

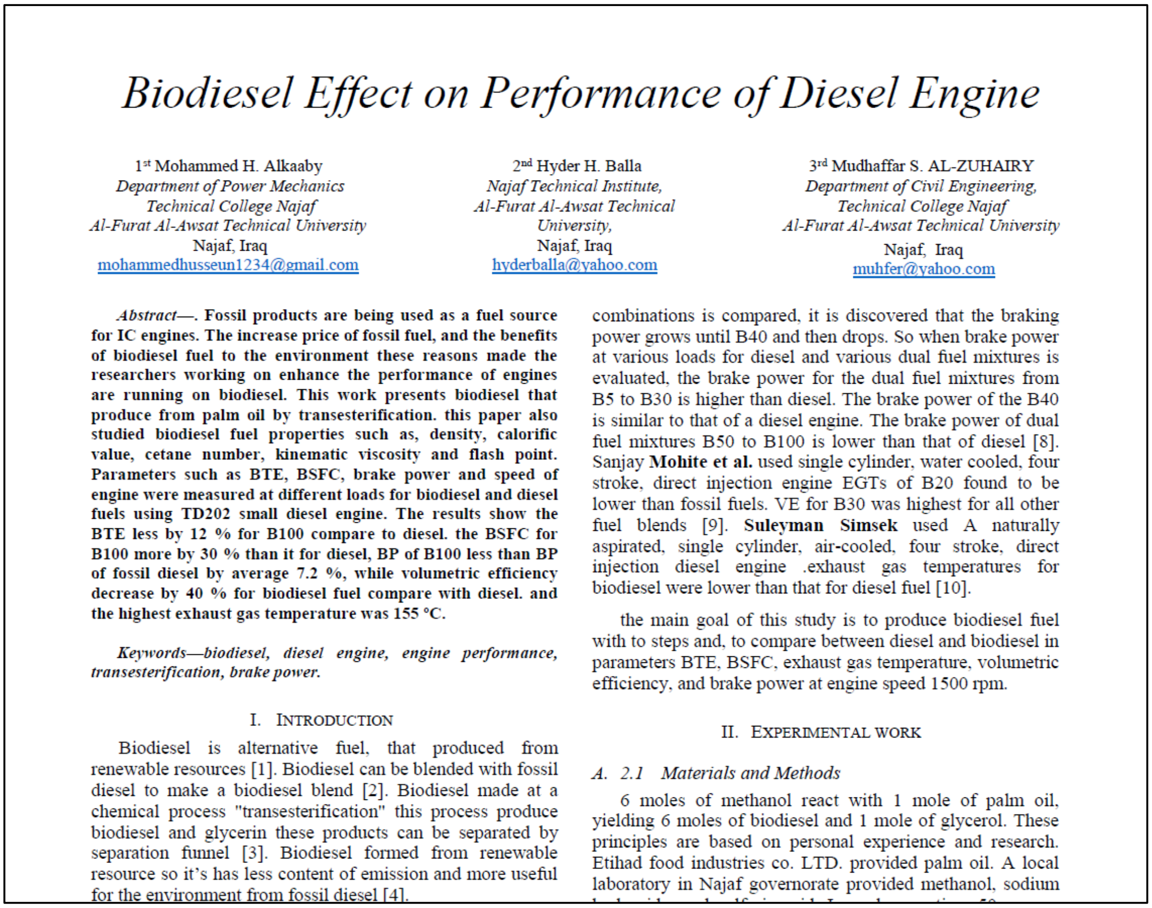
Regards,

Ming Dong Chi,

Editor in Chief
Advances in Mechanics
http://advancesinmech.com

3- Under review in **case studies in thermal engineering** journal (**Performance and emissions characteristics of a diesel engine fuelled with palm olein oil biodiesel**)

4- Under review (Biodiesel Effect on Performance of Diesel Engine) submit for (2021 IEEE 19th Student Conference).



Biodiesel Effect on Performance of Diesel Engine

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***Abstract*—. Fossil products are being used as a fuel source for IC engines. The increase price of fossil fuel, and the benefits of biodiesel fuel to the environment these reasons made the researchers working on enhance the performance of engines are running on biodiesel. This work presents biodiesel that produce from palm oil by transesterification. this paper also studied biodiesel fuel properties such as, density, calorific value, cetane number, kinematic viscosity and flash point. Parameters such as BTE, BSFC, brake power and speed of engine were measured at different loads for biodiesel and diesel fuels using TD202 small diesel engine. The results show the BTE less by 12 % for B100 compare to diesel. the BSFC for B100 more by 30 % than it for diesel, BP of B100 less than BP of fossil diesel by average 7.2 %, while volumetric efficiency decrease by 40 % for biodiesel fuel compare with diesel. and the highest exhaust gas temperature was 155 °C.**

Keywords—biodiesel, diesel engine, engine performance, transesterification, brake power.

I. INTRODUCTION

Biodiesel is alternative fuel, that produced from renewable resources [1]. Biodiesel can be blended with fossil diesel to make a biodiesel blend [2]. Biodiesel made at a chemical process "transesterification" this process produce biodiesel and glycerin these products can be separated by separation funnel [3]. Biodiesel formed from renewable resource so it's has less content of emission and more useful for the environment from fossil diesel [4].

combinations is compared, it is discovered that the braking power grows until B40 and then drops. So when brake power at various loads for diesel and various dual fuel mixtures is evaluated, the brake power for the dual fuel mixtures from B5 to B30 is higher than diesel. The brake power of the B40 is similar to that of a diesel engine. The brake power of dual fuel mixtures B50 to B100 is lower than that of diesel [8]. Sanjay **Mohite et al.** used single cylinder, water cooled, four stroke, direct injection engine EGTs of B20 found to be lower than fossil fuels. VE for B30 was highest for all other fuel blends [9]. **Suleyman Simsek** used A naturally aspirated, single cylinder, air-cooled, four stroke, direct injection diesel engine .exhaust gas temperatures for biodiesel were lower than that for diesel fuel [10].

the main goal of this study is to produce biodiesel fuel with to steps and, to compare between diesel and biodiesel in parameters BTE, BSFC, exhaust gas temperature, volumetric efficiency, and brake power at engine speed 1500 rpm.

II. EXPERIMENTAL WORK

A. 2.1 Materials and Methods

6 moles of methanol react with 1 mole of palm oil, yielding 6 moles of biodiesel and 1 mole of glycerol. These principles are based on personal experience and research. Etihad food industries co. LTD. provided palm oil. A local laboratory in Najaf governorate provided methanol, sodium

الخلاصـــة

تهدف هذه الدراسة إلى مقارنة أداء المحرك وانبعاثات العادم لمحرك CI باستخدام وقود الديزل الحيوي وخلائطه كوقود عامل بدلاً من وقود الديزل. تصف الدراسة في البداية معالجة النسبة العالية من الأحماض الدهنية الحرة في الزيوت النباتية بالأسترة المحفزة بالحمض. بعد معالجة الزيت النباتي يتم إجراء الاسترة التبادلية بين الزيت النباتي والميثانول بنسبة مولارية تبلغ 6:1. من هذه العملية ، يتم إنتاج وقود الديزل الحيوي والجلسرين. يتم غسل وتجفيف وقود الديزل الحيوي ثم بعد ذلك تتناول الدراسة حساب الخصائص الفيزيائية والكيميائية للوقود المنتج ومقارنتها بالقيم القياسية للديزل الحيوي EN 14214.

في هذه الدراسة ، تم عمل مخاليط بين وقود الديزل والديزل الحيوي بواسطة (B10) ، (B20) ، (B50) ، (B70) .

كانت معايير أداء المحرك هي استهلاك الوقود والكفاءة الحرارية والكفاءة الحجمية عند سرعات مختلفة للمحرك (1000 ، 1500 ، 2000 ، 2250 ، 2500 دورة في الدقيقة) والأحمال المتغيرة (0 ، 25 ، 50 ، 75 ، و 100٪) ، وكذلك الانبعاثات (اول أوكسيد الكربون وثاني أكسيد الكربون والهيدروكربونات وأكاسيد النيتروجين).

انخفضت الكفاءة الحرارية لخلائط الوقود B10 و B20 و B50 و B70 و B100 بقيم 0.76٪ و 1.53٪ و 2.56٪ و 3٪ و 3.66٪ على التوالي مقارنة بوقود الديزل الأحفوري. زاد استهلاك الوقود بمقدار 0.087 كجم / كيلوواط ساعة ، و 0.15 كجم / كيلوواط ساعة ، و 0.212 كجم / كيلوواط ساعة ، و 0.286 كجم / كيلوواط ساعة ، و 0.344 كجم / كيلوواط ساعة ، على التوالي ، مقارنة بوقود الديزل الأحفوري . تظهر الكفاءة الحجمية سلوكًا سلبيًا مع زيادة حمل المحرك وخلط الوقود البديل أو المخصص حيث يتناقص. تتناقص الطاقة مع زيادة النسبة المئوية للديزل الحيوي في مخاليط الوقود مقارنة بوقود الديزل الأحفوري.هناك انخفاض كبير في انبعاثات غاز العادم في (CO و HC) باستخدام وقود الديزل الحيوي وزيادة في جميع توليفات الديزل الحيوي مقارنةً بوقود الديزل الحيوي. زيادة وقود الديزل و (CO_2 و NOx) مقارنة بوقود الديزل. تم العثور على الحد الأقصى لانبعاثات ثاني أكسيد الكربون عند B100 بنسبة (84.1٪) ، وتم العثور على انبعاثات HC عند B100 بنسبة (17٪) تزداد درجة حرارة غاز العادم مع زيادة حمل المحرك. بالنسبة لنفس حمل المحرك والسرعة ، فقد وجد أن درجات حرارة غاز العادم لوقود الديزل تكون أعلى في جميع أحمال المحرك مقارنة

بوقود الديزل الحيوي. كانت أقصى درجة حرارة لغاز العادم تم الوصول اليها 227 درجة مئوية للوقود لسرعة المحرك تساوي 2500.

وقود الديزل الحيوي لمحركات الاحتراق الداخلي

رسالة مقدمة الى

قسم هندسة تقنيات ميكانيك القوى في الكلية التقنية الهندسية-نجف /جامعة الفرات الاوسط التقنية

كجزء من متلطبات نيل درجة الماجستير في هندسة تقنيات ميكانيك الحراريات

تقدم بها

محمد حسين عبدزيد جواد

اشراف

الاستاذ المساعد الدكتور
حيدر حسن عبد

الاستاذ الدكتور
مظفر صادق الزهيري

1442 هـ

جمهورية العراق
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جامعة الفرات الاوسط التقنية
الكلية التقنية الهندسية-النجف

وقود الديزل الحيوي لمحركات الاحتراق الداخلي

محمد حسين عبدزيد جواد

ماجستير في هندسة تقنيات ميكانيك القوى

1442 هـ