INVESTIGATION OF THE EFFECT OF PALM OIL BIODIESEL/DIESEL FUEL BLENDS ON DIESEL ENGINE EMISSIONS AT DIFFERENT INJECTION ADVANCE AND ENGINE LOAD WITH ANSYS

2023
MASTER THESIS
Mechanical ENGINEERING

Mahdi NASSER

Thesis Advisor
Assoc. Prof. Dr. Samet USLU

INVESTIGATION OF THE EFFECT OF PALM OIL BIODIESEL/DIESEL FUEL BLENDS ON DIESEL ENGINE EMISSIONS AT DIFFERENT INJECTION ADVANCE AND ENGINE LOAD WITH ANSYS

Mahdi NASSER

Thesis Advisor

Assoc. Prof. Dr. Samet USLU

T.C.

Karabük University

Institute of Graduate Programs

Department of Mechanical Engineering

Prepared as

Master Thesis

KARABUK

January 2023

I certify that in my opinion the thesis submitted by Mahdi Hussein Nasser titled "INVESTIGATION OF THE EFFECT OF PALM OIL BIODIESEL/DIESEL FUEL BLENDS ON DIESEL ENGINE EMISSIONS AT DIFFERENT INJECTION ADVANCE AND ENGINE LOAD WITH ANSYS" is fully adequate in scope and in quality as a thesis for the degree of Master of Science.

Assoc. Prof. Dr. Samet USLU ....
Thesis Advisor, Department of Mechanical Engineering

This thesis is accepted by the examining committee with a unanimous vote in the Department of Mechanical Engineering as a Master of Science thesis. 16 01 2023

Examining Committee Members (Institutions)		Signature
Chairman	: Assist. Prof. Dr. Suleyman SIMSEK (IAU)	....
Member	: Assoc. Prof. Dr. Samet USLU (KBU)	....
Member	: Assoc. Prof. Dr. M. Erdi. KORKMAZ(KBU)	....

The degree of Master of Science by the thesis submitted is approved by the Administrative Board of the Institute of Graduate Programs, Karabuk University.

Prof. Dr. Muslum KUZU ....
Director of the Institute of Graduate Programs

“I declare that all the information within this thesis has been gathered and presented in accordance with academic regulations and ethical principles and I have according to the requirements of these regulations and principles cited all those which do not originate in this work as well.”

Mahdi Hussein Nasser

ABSTRACT

M. Sc. Thesis

INVESTIGATION OF THE EFFECT OF PALM OIL BIODIESEL/DIESEL FUEL BLENDS ON DIESEL ENGINE EMISSIONS AT DIFFERENT INJECTION ADVANCE AND ENGINE LOAD WITH ANSYS

Mahdi Hussein NASSER

Karabük University
Institute of Graduate Programs
The Department of Mechanical Engineering

Thesis Advisor:
Assoc. Prof. Dr. Samet USLU

January 2023, 63 pages

Exploring the common effects of various operating conditions on diesel engine performance and emission characteristics is important since operating factors have a significant impact on engine emissions and performance. This study aims to determine the impacts of the palm oil ratio, injection advance, and engine load on the efficiency and emission characteristics of diesel engines by using software ANSYS because using software is a great option because it will reduce the cost of all the experiment and can also give a high accuracy result. The main purpose of this study is to conduct several experiments on the palm oil fuel under several properties like viscosity, density and more. Results are compared with the pure diesel. The experiments revealed that the break thermal efficiency (BTE) value increased when palm oil biodiesel was used. According to the emissions results, it was obvious that there is a decrease in carbon monoxide (CO) emissions.

While using palm oil biodiesel fuels, the hydrocarbon (HC) and smoke emissions are decreasing compared to diesel but on the other side the carbon dioxide (CO_2) and nitrogen oxide (NO_x) are increasing with the elevation of palm biodiesel inside the cylinder. As a result, it can be said that palm oil biodiesel is an alternative fuel suitable for use in diesel engines.

Key Words : Diesel engine, Performance, Emission, Alternative Fuel, Palm Oil Biodiesel, Computational fluid dynamics.

Science Code : 91413

ÖZET

Yüksek Lisans Tezi

PALM YAĞI BİYODİZEL/DİZEL YAKIT KARIŞIMLARININ FARKLI PÜSKÜRTME AVANSI VE MOTOR YÜKÜNDE DİZEL MOTOR EMİSYONLARINA ETKİSİNİN ANSYS İLE İNCELENMESİ

Mahdi Hussein NASSER

Karabük Üniversitesi
Lisansüstü Eğitim Enstitüsü
Makine Mühendisliği Anabilim Dalı

Tez Danışmanı:
Doç. Dr. Samet USLU
Ocak 2023, 63 sayfa

Çeşitli çalışma koşullarının dizel motor performansı ve emisyon özellikleri üzerindeki ortak etkilerinin araştırılması, çalışma faktörlerinin motor emisyonları ve performansı üzerinde önemli bir etkiye sahip olması nedeniyle önemlidir. Bu çalışma, palmiye yağı oranı, enjeksiyon avansı ve motor yükünün dizel motorların verim ve emisyon karakteristikleri üzerindeki etkilerini ANSYS yazılımı kullanarak belirlemeyi amaçlamaktadır çünkü yazılım kullanmak tüm deneylerin maliyetini azaltacağı için harika bir seçenektir ve ayrıca yüksek doğrulukta sonuç verebilir. Bu çalışmanın temel amacı, palmiye yağı yakıtı üzerinde viskozite, yoğunluk ve daha birçok özellik altında çeşitli deneyler yapmak ve saf dizel ile karşılaştırmaktır. Deneyler, palmiye yağı biyodizeli kullanıldığında fren termal veriminin (BTE) arttığını ortaya koymuştur. Emisyon sonuçlarına göre de karbon monoksit (CO) emisyonlarında azalma olduğu aşikardır. Palmiye yağı biyodizel yakıtları kullanılırken dizele göre hidrokarbon (HC) ve duman emisyonları azalırken, diğer yandan palmiye biyodizelinin silindir içerisinde artmasıyla birlikte karbondioksit (CO2) ve nitrojen oksit (NOx) artmaktadır. Sonuç olarak palmiye yağı biyodizelinin dizel motorlarda kullanıma uygun bir alternatif yakıt olduğu söylenebilir.

Anahtar Kelimeler : Dizel motor, Performans, Emisyon, Alternatif Yakıt, Palmiye Yağı Biyodizel, Hesaplamalı akışkanlar dinamiği.

Bilim Kodu : 91413

ACKNOWLEDGMENT

Initially, it is my pleasure to express my gratitude to my project advisor, Assoc. Prof. Dr. Samet Uslu, for granting me this chance to go through enriching my thesis. Without his cooperation, this project was not likely. I take this opportunity to show gratitude to my advisor for his valuable guidance and suggestions throughout this thesis.

I additionally want to show gratitude to my dear family for supporting me during my entire master's program.

CONTENTS

Page

APPROVAL ii
ABSTRACT iv
ÖZET vi
ACKNOWLEDGMENT viii
CONTENTS ix
LIST OF FIGURES xi
LIST OF TABLES xiii
SYMBOLS AND ABBREVITIONS INDEX xiv

PART 1 1
INTRODUCTION 1
Theoretical Background 3
1.1.1. History of Diesel 3
1.1.2. History of Biodiesel 7
1.2. SIGNIFICANCE OF THE RESEARCH 10
1.3. RESEARCH QUESTIONS 11
1.4. ASSUMPTIONS 11
1.5. LIMITATIONS 12

PART 2 13
LITERATURE REVIEW 13

PART 3 19
EMISSIONS ON DIESEL ENGINE 19
3.1. CO Emissions 20
3.2. HC Emissions 21
3.3. PM Emissions 21
3.4. NO_x Emissions 22

Page

3.5. SO_2 Emissions 23

PART 4 24
MATERIAL AND METHOD 24
4.1. Palm Oil Biodiesel Production 26
4.2. Preparation of biodiesel 28
4.3. Transesterification process 29

PART 5 33
RESULTS 33
5.1. Engine Performance 33
5.2. BTE Results 45
5.3. BSFC Results 47
5.4. HC emissions 48
5.5. CO emissions 49
5.6. NO_x Emissions 50
5.7. Smoke Emissions 52
5.8. EGT Emissions 53

PART 6 55
CONCLUSION 55
REFERENCES 56
RESUME 64

LIST OF FIGURES

Page

Figure 2.1. Results of CFD and Experiment 15
Figure 2.2 Fuel Type Based on Engine load 16
Figure 2.3. Experiment setup 18
Figure 3.1. Percentage Pollutant Emissions 19
Figure 4.1. Mesh. 24
Figure 4.2. Yield Oil Per Hectare at Oilseeds 27
Figure 4.3. Palm Oil Biodiesel Process 28
Figure 4.4. Transesterification Operation 30
Figure 4.5. Transesterification Process 31
Figure 5.1. Diesel Chemical Formula. 33
Figure 5.2. Palm Oil Biodiesel Chemical Formula. 34
Figure 5.3. CO_2 Mass Fraction On Diesel. 35
Figure 5.4. CO_2 Mass Fraction On Biodiesel. 35
Figure 5.5. Diesel Density. 36
Figure 5.6. Palm Oil Biodiesel Density. 37
Figure 5.7. Viscosity For Diesel. 38
Figure 5.8. Viscosity For Biodiesel. 38
Figure 5.9. H_2O Mass Fraction for Diesel. 39
Figure 5.10. H_2O Mass Fraction For Biodiesel. 40
Figure 5.11. O_2 Mass Fraction In Diesel. 41
Figure 5.12. O_2 Mass Fraction In Biodiesel. 41
Figure 5.13. Diesel Pressure. 42
Figure 5.14. Palm Oil Biodiesel Pressure. 43
Figure 5.15. Temperature in Diesel. 44
Figure 5.16. Temperature in Palm Oil Biodiesel. 44
Figure 5.17. BTE with Respect To Engine Load. 46
Figure 5.18. BSFC with Respect To Engine Load. 47
Figure 5.19. HC with Respect To Engine Load. 48

Page

Figure 5.20. CO with Respect To Engine Load. 49
Figure 5.21. NO_x with Respect to Engine Load. 51
Figure 5.22. Smoke Emissions with Respect to Load an Engine. 52
Figure 5.23. EGT with Respect to Engine Load. 53

LIST OF TABLES

Page

Table 4.1. Properties Biodiesel/Diesel. 26

SYMBOLS AND ABBREVITIONS INDEX

SYMBOLS

Kg/m^3	*: Kilogram Per Cubic Meter*
Mm^2/s	*: One Meter Squared Per Second*
$^{\circ}C$	*: Celsius*
kJ/Kg	*: Kilojoule Per Kilogram*
Mg/kg	*: Milligram or Kilogram*
Pa	*: Pascal*
K	*: Kelvin*
m/s^{-1}	*: Meter Per Second*
PPm	*: Particle Per Million*
W	*: Watt*

ABBREVITIONS

CI	: *Compression Ignition*
CFD	: *Computational Fluid Dynamics*
CSTR	: *Continuously Stirred Tank Reactor*
PBDF	: *Petroleum Based Diesel Fuel*
CO_2	: *Carbon Dioxide*
H_2O	: *Water*
CO	: *Carbon Monoxide*
HC	: *Hydrocarbon*
NO_x	: *Nitrogen Oxides*
Pm	: *Particulate Matter*
SO_2	: *Sulfur Dioxide*
N_2	: *Nitrogen*
O_2	: *Oxygen*
BTE	: *Brake Thermal Efficiency*
BSFC	: *Brake Specific Fuel Consumption*
WCO	: *Waste Cooking Oil*
ULSD	: *Ultra-Low Sulfur Diesel*
EGT	: *Exhaust Gas Temperature*
NO_2	: *Nitrogen Dioxide*
NO	: *Nitrogen Oxide*
SO_3	: *Sulfur Trioxide*

PART 1

INTRODUCTION

Due to their great power, energy efficiency, and wide variable torque, Engines using compression ignition (CI) have recently gained more popularity compared to gasoline engines. It evolved into a common power source for the transportation sector and agriculture machinery during the 20th century. Diesel engines send fewer pollutants into the environment than gasoline engines, even though certain of these emissions have been linked to cancer. The pollutants from diesel engines contribute to global warming, which has recently been worse for people's health. Thus, as a substitute for diesel fuel, this led many researchers to focus on bio-derived fuels. The development of vegetable oil-based biofuels has also been influenced by the rising demand for alternative fuel owing to the rapidly diminishing supply of petroleum diesel. The generation of non-edible vegetable oils used to make biofuels is favored due to the greater cost of edible vegetable oils [1]. Nowadays, there is virtually little study on using commercially available vegetal oils that are not edible replace petroleum fuel. In this study, a Waste Cooking Oil (WCO) that has been esterified and has fuel characteristics comparable to those of diesel is utilized in place of diesel [2]. In comparison to diesel, WCO has a higher viscosity because of its chemical composition and dense molar mass. This is the main thing that prevents WCO diesel engines from being used [3]. Due to increased WCO viscosity, fuel atomization and spray properties are substantially impacted by the growth in fuel droplet size, which lowers performance and increases hazardous gas emissions [4]. The WCO Various chemical pretreatment methods can be used to reduce the viscosity of oil., with transesterification being one of the most often used ways globally [5].

Finding alternative based on renewable and natural resources, such as fats and oils from plants, to replace fossil fuels is crucial. Triglycerides make up 80–90% of oil and fats, with a very small quantity of oxygenated mono- and di-glycerides structure Diesel fuels made from petroleum differ chemically from vegetable oils in several ways. Diesel fuel is made up of hydrogen and carbon that are organized in a chain, either straight or branched patterns without any oxygen (O_2) compounds. Before switching to vegetable oils for diesel fuel, more research is needed. High viscosity and low volatility make them, oils used in diesel engines have been linked to a variety of difficulties. These deposits are created in the fuel injector [6].

Due to its high-quality exhaust, sustainability, and biodegradability, biodiesel has been attracting significant attention on a global scale as an alternative to diesel fuel. Mon alkyl esters, often known as biodiesel, are produced by combining vegetable and animal fats with alcohols with a lower molecular weight when catalysts are present. As hydrophobic compounds from the plant and animal realms, animal fats and vegetable oils are frequently insoluble in water (H_2O). They consist of three moles of fatty acids and one mole of glycerol [7].

The most effective prime mover now in use is the diesel engine. Many of the world's vehicles and machines are powered by diesel engines, which also produce electricity more cheaply. than any other device of a similar size. However, diesel is one of the biggest, and will continue to be one of the biggest, sources of global environmental pollution problems Expected increases in the number of vehicles and vehicle miles is the primary factor contributing to rising world emissions. Diesel emissions cause cancer, heart and lung problems, soil contamination, air, H_2O, and soil pollution, decreased visibility, and global climate change [8].

Earth-moving machinery, tractors, propeller planes, ocean liners, ships, and a variety of utility devices (such as pumps, mowers, chainsaws, portable generators, etc.) are all powered by internal combustion (IC) engines [9]. For a variety of vegetable oils, including soybean, rapeseed, sunflower, and safflower seed, transesterification reactions have been examined. For transesterification, sodium methoxide are often used catalysts. But sodium methoxide also produces several unwanted byproducts, primarily sodium salts, which must be disposed of as trash [10–12]. According to several researches, when using vegetable oil ester as a fuel in diesel engines, hazardous exhaust emissions were reduced, and the engines' performance was on par with diesel. [13–17].

As a substitute for diesel, the term "biodiesel" refers to methyl or ethyl fatty acid esters made from vegetable or animal fats. It is breathable, renewable, and biodegradable. There are still some oppositions to utilizing it, even though several studies have shown that it might aid in lowering emissions of greenhouse gases, encouraging long-term rural development, and improving income allocation. The main reason is a dearth of fresh information regarding biodiesel's impact on diesel engines. The early research findings, such as the fact that biodiesel is more susceptible to oxidation and may produce insoluble compounds, as a result, have been kept in the minds of many people. For instance, the decrease in fuel for a biodiesel engine and there hasn't been as much of an increase in gasoline usage as expected [18]. The fruit's mesocarp of the oil-palm tree is used to produce palm oil, an edible vegetable oil (Elaeis guineensis). It is possible to trace the origin of this variety of palm tree to an area along the African coast between Liberia and Angola [19]. The Malaysian Palm Oil Research Institute (PORIM) was founded in 1988 has been looking into the potential for turning fuels made from oil palm products. The usage of palm oil's methyl ester as a substitute for diesel was one of the third products. Technically speaking, PORIM, Malaysia's usage methyl esters as fuel proven to be a highly effective way to acceptable replacement. Palm oil diesel is the name of the palm oil's methyl ester (POD). Several studies examined the physic-chemical characteristics of POD, or palm oil methyl ester [20].

Theoretical Background

1.1.1. History of Diesel

The engineer Rudolf Diesel applied for a patent on February 27, 1892, a "new rational heat engine" was proposed., at the Imperial Patent Office in Berlin. He received patent on February 23, 1893, for the "Working Method and Design for

Combustion Engines," which was filed on February 28, 1892. As may be inferred from his history, Diesel had set himself a goal that had been bothering him ever since he was a college student. This was a significant first step toward that aim. On March 18, 1858, Rudolf Diesel was born in Paris to German parents. When the 1870–1871 Franco–Prussian War began, he was still in school and traveled through London to Augsburg, where he was raised by foster parents. Rudolf Diesel was a young man. forced to grab control of his life and support himself by, among other things, providing individual lessons, because he lacked support from his family and money. In the end, scholarships allowed him to attend the Polytechnikum München, subsequently known as the Technical University, where he was the top examinee when he graduated in 1880. to have ever taken the course. Diesel learned that the steam engine, the predominant heat engine of the time, loses a large amount of energy as compared to the ideal energy conversion cycle proposed by Carnot in 1824 during the caloric machine theory lectures by Professor Linde. Additionally, the furnaces and boilers in the time produced annoyance smoke that badly fouled the air and had efficiency levels of just around 3% [21].

Even as a student, Diesel considered using the Carnot cycle to convert coal's energy into heat without the use of steam as an intermediary medium, according to lecture notes that have survived. He ambitiously pursued the notion of a rational engine while working at Lindes Eismaschinen, which carried him from Paris to Berlin. He hoped that his innovation would grant him financial freedom as well as social development. A functioning piston compresses clean air, so forcefully the temperature in a cylinder produced because of this, is far higher than the fuel's ignition temperature being utilized. This is the ultimate working mechanism for combustion engines. Then, as a result of the air pressure and the ejecting piston (or gas) expanding the outcome, In order to prevent pressure and temperature from drastically rising during combustion, the fuel is fed progressively starting at dead center. Consequently, when the fuel supply is cut off, the gas mass in the operating cylinder increases even further. Heat dissipates along the isobars to finish the cycle after To the discharge pressure, the gas has been decompressed. He did not, however, rule out other fuels, as subsequent studies, including ones using vegetable oils and other materials, demonstrate. Nobody could have known which gasoline was which, not even diesel optimal because of the diesel engine when compared to the "state-of-the-art" of the time [22].

.

The multiple-stage compression and expansion is protected by patent. is claimed in a second claim. A compound three-cylinder engine was proposed by diesel. two cylinders with high pressure 2, 3, which are adjusting their clocks in 1808, experience adiabatic compression, and first the fuel diesel mentioned coal dust delivered top dead center from the hopper B automatically sparks to promote isothermal combustion, which expands at a temperature that turns adiabatic after combustion is complete. It is the combustion gas. introduced into the first double acting center cylinder fully increases to atmospheric pressure before being after the motion, ejected is reversed, concurrent with the water injection method for isothermal precompression or the prior intake of new charge for the parallel second engine cycle. Thus, each rotation is followed by one cycle. Diesel went back to the four-stroke cycle that has been called "state-of-the-art" since Nikolaus Otto's time to execute the Carnot cycle. Keeping If the engine's thermal load were low enough, allow him to operate it without cooling, he reasoned, using isothermal combustion at a maximum temperature of 8008ºC. Diesel considerably outperformed the "state-of-the-art" at compressions of about 250 at this limiting temperature. On one hand, this provided diesel the naivete of an "outsider". Need to put his proposal into action, on the other hand, companies with a history in engine production, like the Deutz gas engine manufacturer, avoided diesel's initiative. Pescara started experimenting on free-piston engines about 1922, and in 1925, he created prototypes that combine diesel combustion with spark ignition (1928) [23].

Diesel gave instructors a paper he had written titled "Theory and Design of a Rational Heat Engine" and businessmen in addition to Deutz at the turn of the 1892–1893 period to spread his ideas and gain the support of industry. Diesel was aware that "the concept and the invention's execution" are the two components of an innovation. He anticipated 30 to 40% maximum losses in actual a process that would translate 50% net efficiency, with a Carnot efficiency of around 73% at 8008ºC. Diesel ultimately signed a contract using the prestigious Maschinenfabrik Augsburg AG, conducted by Heinrich Buz, a top steam engine maker, in early 1893 after nearly a year of work and planning. The contract included concessions made by diesel to a perfect engine, including a highest-pressure reduction from 250 to 90 pa and eventually at 30 pa, the elimination of coal dust as a fuel, and the reduction of three cylinders of the compound engine to one high pressure cylinder. The deal, which was profitable for Diesel, was engaged into by two other producers of heavy machinery, Krupp, and Sulzer shortly after [24].

Early in the summer of 1893, work on the first test engine without a cooling system 400 mm stroke and 150 mm bore started in Augsburg. The first-time a powered engine received gasoline injection occurred tenth of august 1893, even though petroleum was the planned fuel because of the mistaken belief that it would ignite more quickly. The indication exploded at pressures exceeding 80 bar, but the theory of auto-ignition was nevertheless validated. was changed, received water cooling afterwards, and could not be directly inserted. It could only be atomized or injected, and ignited air is compressed, though. On February 17, 1894, the previously powered engine idling for the first time made it independent. The first brake test was finally conducted utilizing petroleum as the fuel and externally compressed infusion air on June 26, 1895. At a consumption of 382 g/HPh, an indication of Zi's effectiveness 14 30.8% and a Ze net efficiency 14 16.6% were assessed. However, several issues with the twin piston design have been identified [25].

The breakthrough was nevertheless only made possible by a redesigned the third test engine for design equipped the use of a single-stage air pump: On February 17, 1897, Technische Hochschule München Professor Moritz Schroter administered admissions exams. On June 16, 1897, in Kassel, he presented the findings along with Diesel and Buz before a general assembly of the Association of German Engineers, unveiling the first heat engine, which had a stunning efficiency of 26.2% at the time. It called for giving up the isothermal heat input that the initial patent claimed. Given the small area of the figure proportionate to the effort represented and the anticipated frictional losses due to the high pressures, He thought of increasing the p, V diagram's isothermal heat input line early on, taking great care not to endanger the basic patent in the process. The constant pressure cycle was also mentioned in a subsequent patent application, which was filed on November 29, 1893. It was deemed compatible with the initial invention due to its "insubstantial pressure rise”. The fundamental invention was disregarded by the awarded patent, even though both the fuel mass and the maximum temperature rose. Unsurprisingly, Kassel patent issues eventually engulfed Diesel and the Diesel alliance. Diesel's patent claims were allegedly not met by Diesel's engine, which was unable to work without cooling and failed to expand as a result of compression without significantly raising temperature and pressure. There was just the auto-ignition described in claim 1. In contrast, Diesel adamantly denied until the very that auto-ignition was a bad idea fundamental aspect of his innovation, just as he never acknowledged that his engine was incomplete in every way cycle of Carnot. The extra fee for not using coal dust was less significant. Diesel, a 19th-century engineer, first struggled to get around coal, the principal source of vigor throughout his day, especially because his motor was designed replacement for the steam engine. He did not, however, rule out other fuels, as subsequent studies, including ones using vegetable oils and other materials, demonstrate. Nobody could have known which gasoline was which, not even diesel optimal because of the diesel engine when compared to the "state-of-the-art" of the time [26].

1.1.2. History of Biodiesel

M. K. Hubbert, an American geologist, anticipated that oil production in the United States would peak in the late 1960s and early 1970s and then tend to decline once it had reached its maximum [27]. His forecast came true in 1970, the year that American output peaked. Since then, much has been published on Hubbert's theory of peak oil, which predicts that global oil output will peak in the 2000s. Along with others, Simmons and Deffeyes speculate that the highest in global oil output most likely take place in this decade (2010), and they won't climb again. According to Hirsch, oil analysts believe oil will shortly reach its peak. He argues that soon can be within 20 years in his study, which was published in 2005. This sets the time range to conclude at about the year 2025 [28].

However, there is none set time or date for the oil peak, such a situation warrants consideration not only the potential scarcity fossil fuels, as well as the options to lessen it, but also in particular for issues relating to energy security. Even if there are new reserves, they will probably be harder to find, more expensive to drill for, and less accessible. In this regard, certain nations, such as Brazil, have discovered alternative and sustainable energy sources, such as biodiesel made from diverse raw materials and sugar cane ethanol. Concerns regarding the potential environmental effects of manufacture of biodiesel have grown in Brazil during the past ten years. Even though research on life cycle assessment, which are discussed Later on in this essay, have revealed the fact that biodiesel entirely clean, according to certain research claimed that, In contrast to conventional diesel, biodiesel has several environmental advantages. To demonstrate the importance of biodiesel in Brazil in terms of reducing CO_2 emissions, this paper will quickly summarize the research on its background, development, and environmental factors. It will also present the Brazilian biodiesel program's status and discuss potential synergies with similar biofuels initiatives in other developing countries. The majority among the alternative fuels utilized in the world's transportation fleet, according to the 2014 study biodiesel and ethanol were mentioned in the renewable energy policy network for the 21st Century [29].

The same report claims that the Production and use of biofuels worldwide for transportation risen by 7% in just one year, totaling about 116 billion liters, with biofuels accounting the 26 billion of those. Many of this manufacturing and consuming was driven by the market in Europe. The main regional producer of biodiesel has been driven by the European Union market for many years. For instance, in 2013, it produced roughly 10.5 billion liters of methyl esterified fatty acids, even if its percentage of the world market, or about 42%, has remained constant throughout time. Both biofuels have an expanding market share in Brazil, just like they do in the US and other European nations. Among the biofuels, biodiesel saw the most rise during the past ten years, with a 15-fold increase in production volume from 2002 to 2012. On the other hand, the United States' output of biodiesel has expanded quickly, accounting for 17% of the global total and reaching in 2013 4.8 billion liters. the identical year, there were 115 biodiesel manufacturers operating in the United States, with a combined installed capacity of close to 8.5 billion liters. Due to new national biofuel rules, Indonesia, for instance, has significantly expanded its biodiesel output since 2013 and is now one of the world's top producers of the fuel [30].

2013 saw a 30% growth in ethanol and biodiesel output in Thailand. The country's goal for the development of renewable energy was the main factor in this expansion. Tax and commercial incentives helped stimulate the market for biofuels in China, where the government imports 1.9 billion liters of gasoline to supplement its meager annual domestic output a biodiesel production of less than 0.2 billion liters. However, since the government opted to impose a political tax on the importation of biodiesel choice to encourage refineries in the area generate fossil fuel for the national market biodiesel there has suffered a setback. According to REN21, among other oilseeds, coconut and jatropha vegetable oils are being utilized to provide generators for an increasing number of nations in place of fossil fuel. The biofuels biogas and biodiesel were thought to maintain the same kind of usage when using public transit Johannesburg, South Africa. In recent years, Brazil has seen a significant increase in the hunt for a sustainable, technically feasible, and economically viable alternative fuel source. Due to its close compatibility with petroleum-based diesel and status as a largely renewable energy source, biodiesel is occupying space in the Brazilian energy matrix by offering various benefits over mineral diesel, which are mentioned earlier in this study. The 2030 National Energy Plan claims that, a document produced for the department of mines and energy in 2007 by Empresa de Pesquisa Energética (energy research company), No matter where the raw ingredients come from, the goal of producing biodiesel is to continuously minimize the pollution that petroleum diesel causes [31].

Prioritizing the usage of renewable energy was the fundamental principle, which was automatically thought about in the forecast of the total energy consumed. As a result, in all scenarios, liquid fuels produced from oil, particularly gasoline and diesel, may lose market share to biodiesel and ethanol. Therefore, despite everything challenges that biodiesel in Brazil has encountered, in part because of the utter monopoly of soybean as the primary feedstock, If the feedstock distribution has been done in percentages, as biodiesel production and usage have considerably expanded since 2005, its relevance varies by location. The percentages were not required of blending back in 2005, between fossil fuel and 100% pure biodiesel (B100), when the biofuels sector in Brazil started producing biodiesel through the end of 2007. However, the 2% blend was already in existence. However, The Brazilian government changed diesel fuel to include B100 necessary from the beginning of 2008, 2% (B2) from January through June of that year; 3% (B3) from July through June of 2008; 4% (B4) from July through December 2009; and 5% (B5) from January 2010 through June of 2014. Brazil was then the world's fourth-largest producer of biodiesel as a result of rising production and use [32].

1.1. PROBLEM STATEMENT

The non-renewable energy sources coal and fossil fuels dominate the global energy market today. If prompt energy management measures are not done, these energy sources can run out eventually, casting doubt on the future's energy security. Sources of renewable energy introduction and its expanded part in meeting the global energy demand are the greatest solutions to this issue. Diesel must have known the engine couldn't do any useful work as early as when he calculated the theoretical indica tor diagrams.

1.2. SIGNIFICANCE OF THE RESEARCH

A sustainable and clean-burning fuel, biodiesel is created from used vegetable oils for use in diesel vehicles. Palm Oil Biodiesel came to decrease the demand in terms of fossil fuel in the global market, to reduce the toxic pollution and greenhouse gases. Palm oil biodiesel produced from renewable resources unlike other petroleum product. It can be manufactured on demand and emits less pollution than diesel because it is composed of vegetables. Biodiesel can be applied to current diesel engines with little or no modifications at all. Biofuel refineries, which largely use vegetable and animal fat to manufacture biofuel, produce less dangerous substances if spilled or discharged into the environment. A flashpoint exists for biodiesel that is greater than 150ºC, compared to petroleum-based diesel flashpoint of 52ºC, which makes lower flammability. The result is, handling, storing, and transporting it are all safe.

1.3. RESEARCH QUESTIONS

- Can Biodiesel take place the fossil fuel?
- Are Biodiesel better than petroleum diesel?
- Are Biodiesel being the better fuel economy?
- Is compatible with current diesel engines?
- Can biodiesel be less greenhouse gas emissions?
- Can biodiesel improved air quality?

1.4. ASSUMPTIONS

- Biodiesel is a source of renewable energy, as opposed to other petroleum products, which will eventually run out of supply. It can be manufactured on demand and emits less pollutants than petroleum diesel because it is made from animal and vegetable fat.
- Burning biofuels results in very little pollution and a large reduction in carbon emissions. Biodiesel emits less sulfur dioxide (SO_2), more soot, CO, and unburned (HC) than petroleum diesel.
- The availability of fossil fuels may eventually become insufficient to satisfy our need for natural gas, oil, and coal. Biodiesel, which is produced from domestic power plants, may be used as an alternative fuel, and assist in reducing our reliance on foreign oil imports. Local manufacturing eliminates the requirement to import pricey completed goods from other nations.
- The cycle is maintained due to the CO_2 discharged during biodiesel combustion is used during the growth of the crops used to make the fuel for photosynthesis. The process that creates the fuel consumes the likely pollutant. In turn, this cycle aids in rescuing the planet from the grip of global warming. All things considered, utilizing biodiesels greatly improves air quality.

1.5. LIMITATIONS

The tests during this study were directed via computational fluid dynamics (CFD) Ansys on cylinder combustion geometry. Then make a mesh, put properties of the biodiesel, and start testing. Finally figure out the results from Ansys on the performance of the cylinder after before and after using palm oil biodiesel, and the output emissions from the cylinder as showed in the study.

PART 2

LITERATURE REVIEW

Mekhilef et al. [33] analyzed on Malaysian biodiesel production being among the top palm oil manufacturers worldwide, Malaysia uses it as the main raw material to generate biodiesel locally. There are several benefits and drawbacks. associated with generating Malaysian biodiesel, in terms of the economic, social, and environmental factors, palm oil biodiesel stands out. This essay's goal is to analyze Malaysia's palm oil biodiesel industry's past, present, and future. In conclusion, without requiring modifications, an environmentally friendly fuel that may be used in diesel engines is biodiesel. The effective development of biodiesel using energy would advantageous the environment and the community inhabitants since it would offer modern energy sources and employment possibilities to rural residents.

Dhinesh et al. [34] examined the combined impact of exhaust gas recirculation (EGR) and WCO biodiesel/diesel mixes in a twin-cylinder diesel engine. Gas chromatography mass spectrometry was used to analyze the components of the trans-esterified WCO biofuel. The test engine would be best suited for B20 blend gasoline, which has the biggest reductions in unburned HC, CO, smoke, and CO_2 emissions of 17%, 30%, 14.08%, 7.35%, and 16.46%, respectively, in both the simulated and experimental findings. To lower NO_x emissions, EGR was added to at three distinct rates, namely (5%, 10%, and 15%), the chosen B20 mix gasoline.

Mantari and Jaafar. [35] analyzed on how well various palm biodiesel blends perform in an oil burner configuration. This study uses palm biodiesel, a blend of diesel and palm olein, as its biofuel. A biodiesel burner powered by palm oil will function better depending on the temperature distribution and emissions of CO, SO_2, and nitrous oxide. In this work, computational fluid dynamics is widely employed in the combustion chamber to imitate the combustion process. The temperature and biofuel emission both decrease as the blends' palm olein content increases. The B5 blend had the best performance, followed by B10, B15, and then B20. This is true for both the numerical and experimental procedures, even though there is a sizable value difference between them. The Sauter Mean Diameter (SMD) of the biofuel mixes exhibits a similar trend. The least SMDs are found in the mixes B5, B10, B15, and B20. The same patterns may be seen in all three of the separate approaches—PDA, empirical equation, and CFD.

Norhidayah et al. [36] examined to using simulation studies, the combustion properties of several Palm Methyl Ester (PME) mixtures and pure diesel, diesel, ethanol, and diesel, as well as to identify the ideal fuel combination for usage in realistic engine situations. Seven distinct diesel-ethanol PME combinations were used in a simulation investigation using the converge CFD software for a combustion based on the Yanmar TF90 engine's compression ignition feature. Ethanol and PME were combined with diesel to increase the rate of combustion heat release, which increased engine efficiency. Due to the mixes' relatively low temperature and Heat Release Rate (HRR), blends with more than 35 vol% ethanol were not appropriate for use in direct injection compression ignition engines without modification.

M.A. Kalam and H.H. Masjuki. [20] investigated on the results of tests done to ascertain how biodiesel (made from palm oil anticorrosion)'s component will affect Performance, emissions, and wear characteristics of diesel engines. Palm oil's methyl ester is what is meant by the other name for this biodiesel, palm oil diesel (POD). The creation of a third biodiesel engine-friendly lubricant will be based on the study's findings. In conclusion, Palm oil's physical and chemical characteristics are like those of other biodiesels like soybean and rapeseed oils and meet the criteria for diesel engine combustion. In comparison to regular fuel Oil Diesel (OD), fuel B (50 ppm anticorrosion/corrosion inhibitor + 15% POD + 85% OD) boosted brake power while lowering exhaust pollutants. in comparison to OD, it lessens the depletion of additives and wear metals (Fe, Cu, Al, and Pb) (Zn, Ca). For both POD mixtures, viscosity variations are usual. The total base number decreases when mixtures contain POD rises. As a result, POD mixes containing an anticorrosion component were successful.

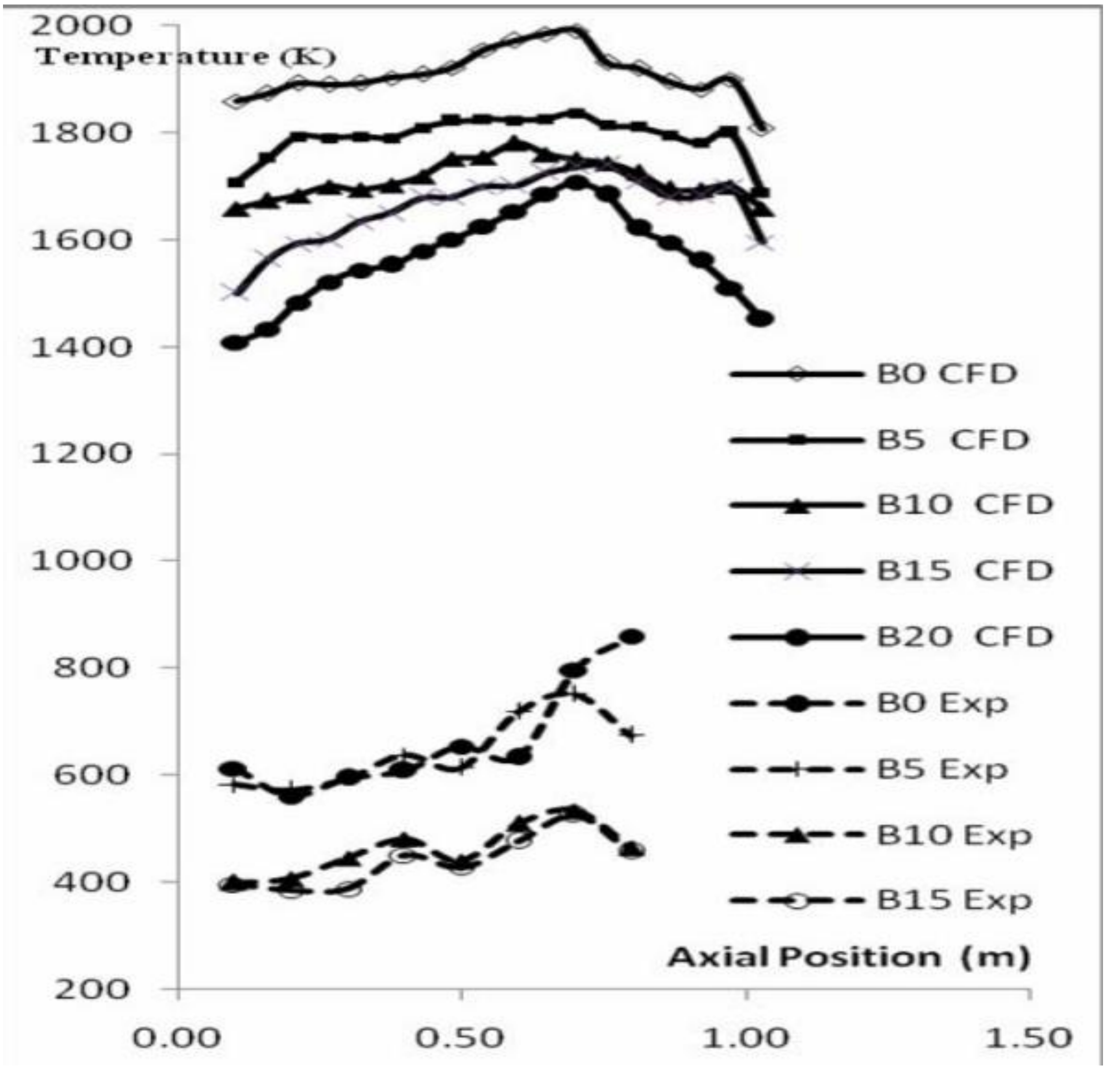

Figure 2.1. Results of CFD and Experiment [20].

Asumin Selemani. [37] investigated to characterize the effects hydrodynamic behavior, temperature, and mixing intensity in a batch continuously stirred tank reactor (CSTR) on the transesterification process, the researcher focused his investigation on a model that employs CFD and optimization using ASPEN PLUS. The impacts of adjusting the impeller speed from 150, 350, and 700 rpm and the temperature from 50, 60, and 65°C were investigated using CFD in ANSYS Fluent 12.1. The model results and the experimental data had a close relationship, and the model findings were validated using data from the published literature. The model could be helpful for the design and optimization of a batch CSTR in the production of biodiesel.

Ozsezen and Canakci. [38] examined the experiment Under the full load-variable speed scenario, the exhaust gases from a unaltered diesel engine powered by methyl ester of used palm oil for frying (biodiesel) and mixtures of it with petroleum-based diesel fuel (PBDF) were examined. The results show that the fuel line pressure increased while the air fuel equivalence ratio and ignition delay reduced when biodiesel was used in the test engine. These actions affected the way biodiesel burnt when compared to PBDF, which reduced the amount of CO emission by 57%, the amount of unburned HC by approximately 40%, and the amount of smoke opacity by about 23%. However, the NO_x and CO_2 emissions from biodiesel showed various patterns depending on the engine speed.

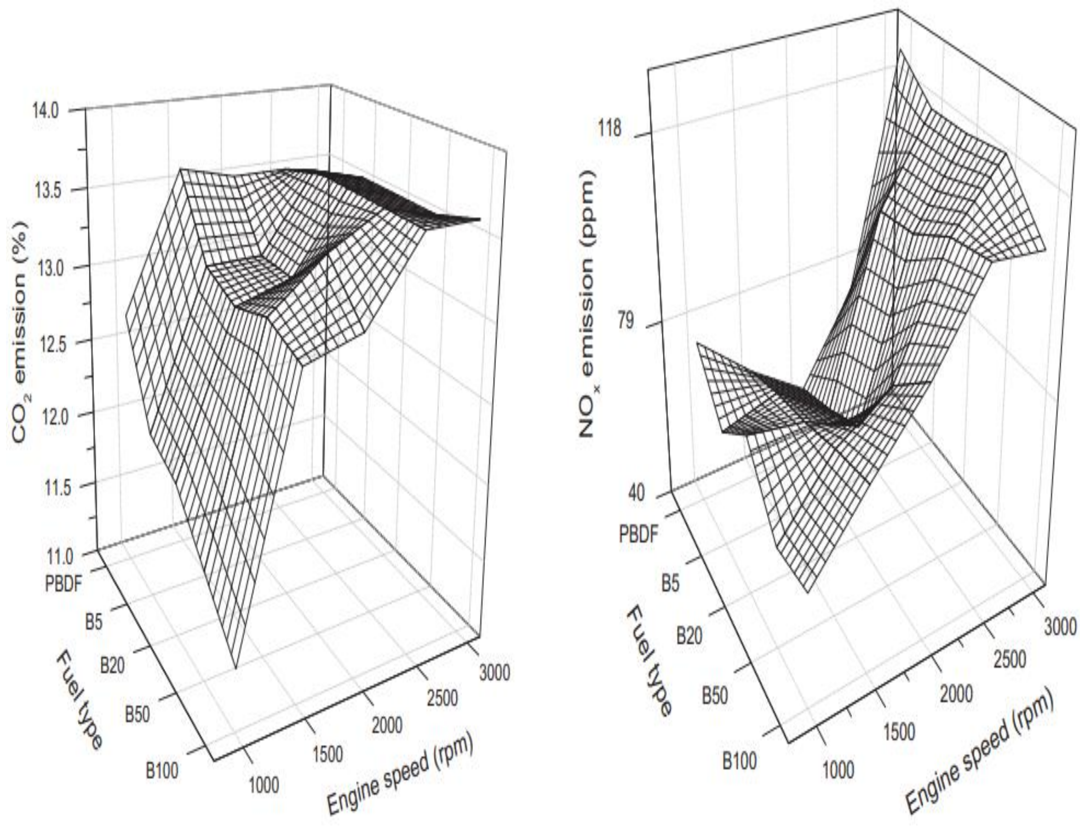

Figure 2.2 Fuel Type Based on Engine load [38].

Devarajan et al. [39] analyzed on his study the effects of using Palm Oil Biodiesel (POBD100) with cyclo-octanol additive in a constant speed diesel engine on engine combustion, emission, and performance were studied. Methanol, sodium hydroxide, and the conventional transesterification process employing palm oil were used to turn the oil into biodiesel. The smooth combustion was attributed to the greater octanol level, according to the experimental data. All octanol and biodiesel mixes offer early combustion as compared to ordinary palm oil biodiesel, which leads to increased thermal efficiency, decreased fuel consumption, a lower peak pressure, and a shorter ignition delay. Cyclo-octanol in palm oil biodiesel lowers all emissions from all loads because of the higher O_2 content of air/fuel mixtures and improved atomization. According to the findings of this study, palm oil biodiesel and cyclo-octanol blends can be utilized as a viable alternative fuel for existing, unmodified diesel engines because of their improved combustion, emission, and performance qualities.

Khan et al. [40] investigated the current study is primarily focused on creating a practical biofuel substitute by mixing aluminum oxide nanoparticles with palm oil. The biofuel was mostly made from non-edible Palm oil utilizing trans-esterification techniques. The procedures included a range of materials, including Methanol and an acid catalyst known as muriatic acid, to accelerate the reaction rate. According to the findings, this oil had a 95% yield, making it acceptable for large production. In-depth experimental investigations on performance indicators such as Brake Power (BP), BTE, and break specific fuel consumption (BSFC) on single-cylinder engines fueled by various biodiesel and diesel fuel blends were also carried out.

Yuvenda et al. [41] carried out an experiment on an alternative fuel to be replaced inside the diesel engine, to improve the combustion process inside the engine and also to reduce bad emissions like CO and HC. Fig (X) shows the experimental setup of this experiment. During the test a single cylinder diesel engine was used powered with palm oil biodiesel, by the using of an electric supercharger, the combustion air was added to the cylinder with the respect of several engine load. As a result, the increase of O_2 concentration improve the air fuel ratio quality, also this lead to a drop in emissions and improve the combustion.

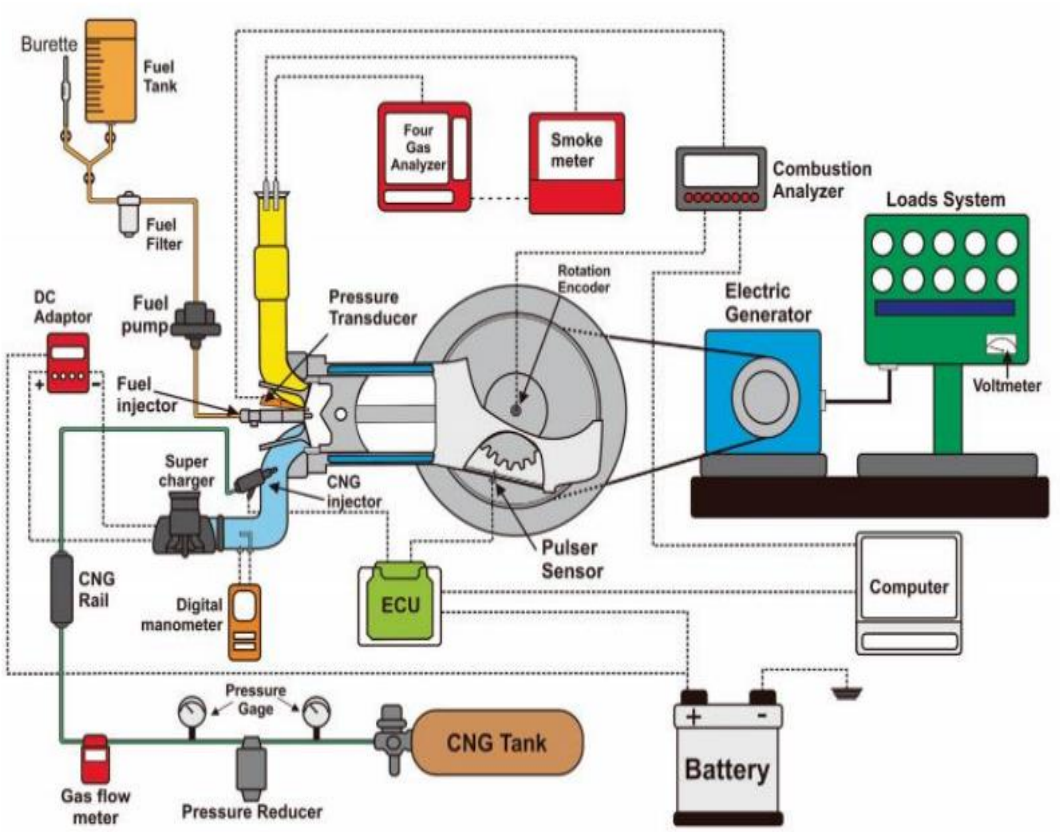

Figure 2.3. Experiment setup [41].

PART 3

EMISSIONS ON DIESEL ENGINE

Once the gasoline and air have been combined, the diesel engine immediately starts. The amount of air needed for burning is quite little inside a combustion engine's chamber. In diesel fuel may spontaneously ignite when pumped into the cylinder because of the hot temperatures that were created. Thus, the chemical energy is released by the diesel engine. Contained in the diesel fuel through heat, which subsequently converts it into mechanical force [42]. Diesel fuel's genesis is carbon and hydrogen, much as other fossil fuels. Under optimal thermodynamic balance, the whole diesel fuel combustion in engine chambers would only result in the production of CO_2 and H_2O [43]. This is disproved by several variables (such as the air-fuel ratio, the length of the ignition, the kind of combustion, the concentration of the air-fuel, the combustion temperature, etc.), and combustion produces several harmful byproducts. The most hazardous chemicals are NO_x, HC, particulate matter (PM), and CO.

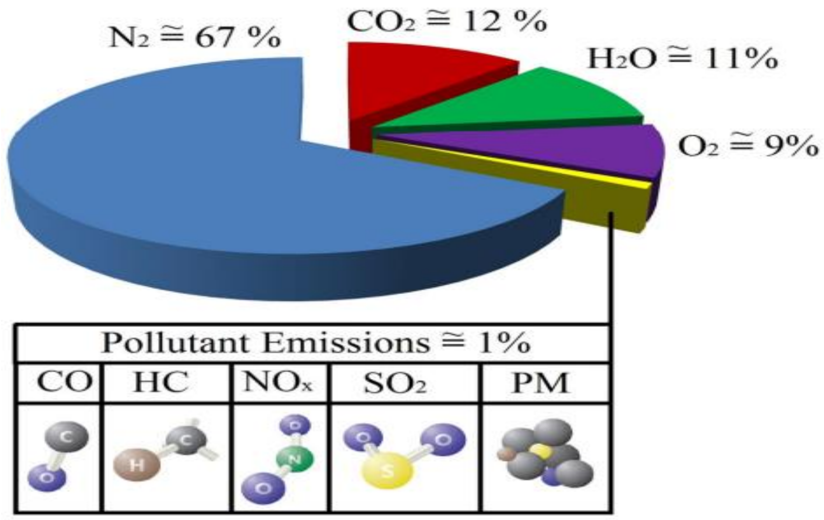

Figure 3.1. Percentage Pollutant Emissions [42].

Fig. 3.1 depicts the overall makeup of diesel exhaust gas in more detail. Pollutants make up less than 1% of diesel exhaust gas. NO_x makes up a rate of greater than 50% for the bulk of diesel's harmful emissions. PM emissions are the second-highest pollutant emissions after NO_x emissions. as a result of diesel engines' incredibly low CO and HC levels and rely on lean combustion. Depending on the specifications and fuel quality, a very small amount of SO_2 could also be included in the pollutant emissions. Due to the sulfates in diesel fuel, it creates. Now, SO_2 cannot be eliminated by aftertreatment technology like a catalytic converter. Most oil distributors and customers currently favor Ultra-Low Sulfur Diesel (ULSD) for diesel engines [44]. This section lists the four main pollutants that diesel engines emit: CO, HC, PM, and NO_x. Each sort of emission is also given its own examination in terms of how it affects environmental and human health concerns.

3.1. CO Emissions

CO is produced when the oxidation process does not fully occur while burning. The air/fuel ratio has a significant impact on this concentration, and rich mixtures those with excess-air factors (lambda>1) smaller than 1 have the highest concentration. When rich mixtures are required, such as when the engine is starting and accelerating fast, it can happen. All the carbon cannot be transformed to CO_2 due to a lack of air and reactant concentration in complex mixtures; instead, CO concentration is formed. Kinetic chemical processes in lean conditions, cause a little quantity of CO to be emitted. even if CO is produced while working with rich mixtures [45].

Lean combustion engines, such as diesel engines, consistently possess high air-to-fuel ratios. Because of this, diesel engines produce less CO. However, CO is created in a diesel motor if the droplets or if the combustion chamber are very big does not create enough turbulence or swirl. CO is an odorless, colorless gas. Airborne CO is breathed in by people, which is subsequently taken up by their lungs and absorbed into their circulation. Hemoglobin is attached to it and is unable to transport O_2. The quantity of CO in the air, which may result in asphyxiation, may have an effect on how effectively some organs function, leading to concentration issues, delayed reflexes, and disorientation [46–49].

3.2. HC Emissions

A result of the cylinder wall's nearby temperature being too low, fuels that are not burned produce HC emissions. Now, the air-fuel mixture's temperature is considerably lower than the cylinder's core temperature [50]. Alkanes, alkenes, and aromatic HC are only a few of the numerous varieties of HC. Commonly, they are expressed in terms of equal CH_4 content [51]. Diesel engines typically only emit trace quantities of HC. Under light loads, most diesel HC emissions happen. The primary contributor to light-load HC emissions is lean air-fuel mixing. Low flame rates that impede or delay combustion during the power stroke are the source of lean blends' high HC emissions are released [52].

The kind of fuel, engine layout, and engine setting all affect how many HC are present in diesel engines. Unpredictable operating conditions also have an impact on HC emissions in exhaust gas. Due to abrupt variations speed of the engine, messy injection, enormous nozzle cavity volumes, substantial injector needle bounce, amounts Using unburned gasoline may escape through the exhaust [53]. Between 50 and 60 percent of total HC emissions come through the tailpipe, whereas between 20 and 35 and 15 to 25 percent come from the crankcase and HC emissions' evaporative losses, respectively [54]. The environment and human health are both negatively impacted by HC. They significantly contribute to the generation of ground-level ozone when combined with other pollution sources. A little over 50% of the pollutants that cause ozone are caused by vehicles. HC have been linked to cancer and also affect the respiratory irritation [55].

3.3. PM Emissions

Emissions of pm from combustion are visible in exhaust gases. Extremely Ashy fuel oil, cylinder lube oil, fuel oil with ash content, and tiny fuel and lubrication oil particles, or sulfates and H_2O may have aggregated to produce them [56]. The fuel's HC and lubricating oil do not completely burn, which results in most particles. According to experimental research, in a typical heavy-duty diesel engine, the particle composition is 41% carbon, 7% unburned fuel, 25% unburned oil, 14%

sulfate and H_2O, and 13% ash and miscellaneous materials [57]. Another research found that unburned lubricating oil (40%) and perhaps other metals (31%) as well as elemental carbon (31%) and sulfates and moisture (14%) and also chemicals make up the bulk of the PM [58].

Diesel engines emit PM at a rate that is six to ten times more than that of gasoline engines. Soot, the Soluble Organic Fraction (SOF), and the inorganic fraction (IF) are the three principal elements of diesel particulate emissions. Soot, sometimes referred to as black smoke, makes up more than half of all PM emissions. SOF is made composed of substantial HC that have condensed or adsorb onto the soot. Among other things, it originates from lubrication oil, unburned fuel, and after-burned chemicals. Very high SOF values are produced by low exhaust temperatures and light engine loads [59–63].

3.4. NO_x Emissions

To ignite the fuel in diesel engines, very compressed air is needed. Initial air introduced into the combustion chamber is mostly composed of N_2 and O_2. The air in the combustion chamber is compressed at or near its peak, and fuel is then quickly injected into this compressed air. Once the fuel burns, heat is produced. At this stage, N_2 from the air is expelled from the engine in the same form as it does when O_2 is burned in the combustion chamber. However, NO_x emissions are created as soon as the N_2 in the cylinders combines with the O_2 there at temperatures higher than 1,600ºC. Therefore, it would be true to say that the two primary parameters influencing the production of NO_x during combustion are temperature and O_2 concentration. The amount of NO_x produced depends on several factors, including maximum temperature, O_2 concentrations, and residence duration in the cylinder. Most of the emitted NO_x is produced early in the combustion process when the piston is still at the top of its stroke. At this point, the flame's temperature is at its highest. The amount of NO_x may increase by as much as three times for every 100ºC increase in combustion temperature [64]. Nitrogen dioxide (NO_2) and nitrogen oxide (NO) are the names of NO_x. 85–95% of NO_x is made up of NO. It gradually changes in the environment into NO_2. Even though NO and N Fig. 3.1 are classified as NO_x, these two pollutants have certain distinctive differences. NO is a gas that has no color or smell.in contrast to NO_2, which a reddish-brown gas having an unpleasant odor [65,66].

3.5. SO_2 Emissions

SO_2 is produced using the sulfur in diesel fuel. The sulfur level of the gasoline affects the amount of SO_2 in the engine exhaust. In the USA and Canada, low sulfur fuels with sulfur content less than 0.05% are being introduced for the majority of diesel engine uses. SO_2 is a poisonous gas that is colorless and has an unpleasant odor. The emissions of sulfate PM are caused by the oxidation of SO_2, which yields sulfur trioxide, a precursor to sulfuric acid. SO_2, the primary source of acid rain, have a significant negative influence on the plant. The fuel oil's sulfur content directly contributes to the emissions of SO_2 This fuel's sulfur is readily converted into SO_2 after burning SO_2. The combustion chamber and exhaust duct may further oxidize a tiny portion of the SO_2, about 3–5%, to sulfur trioxide (SO_3). The precise amount is determined by the temperature and pressure of combustion, extra air, and fuel sulfur concentration. Iron and vanadium oxides are present and function as catalysts to speed up the process. The SO_3 reacts with the water vapor in the exhaust fumes to produce sulfuric acid (H_2SO_4).To comprehend the true essence of N_2 effect on NO, HCs, and CO oxidation across for diesel oxidation catalysts (DOC), we will first review basic understandings on the interactions of SO_2 with the extensively investigated a variety of oxide supports and PGM-based noble metal catalysts in the absence of a reaction environment [67–70].

PART 4

MATERIAL AND METHOD

A dimensions-based cylindrical combustion geometry (1.8 m, 0.225 m) was produced using Ansys Modeler. Ansys was used to mesh the geometry, which is depicted in the Fig. 4.1 and the edges were given names in accordance with the specifications for using boundary conditions. First, draw geometry of dimensions (1.8 m, 0.225m). Second open mesh, we start with turn use advanced size function to off. Insert edge sizing, apply geometry selection, change type to number of divisions, specify number divisions to 50, and behavior to hard. Insert edge sizing 2, apply geometry selection, change the type to number of divisions, specify number of divisions at 10 and behavior to hard. Insert edge sizing 3, apply geometry selection, change the type to number of divisions, specify number of divisions at 200 and behavior to hard.

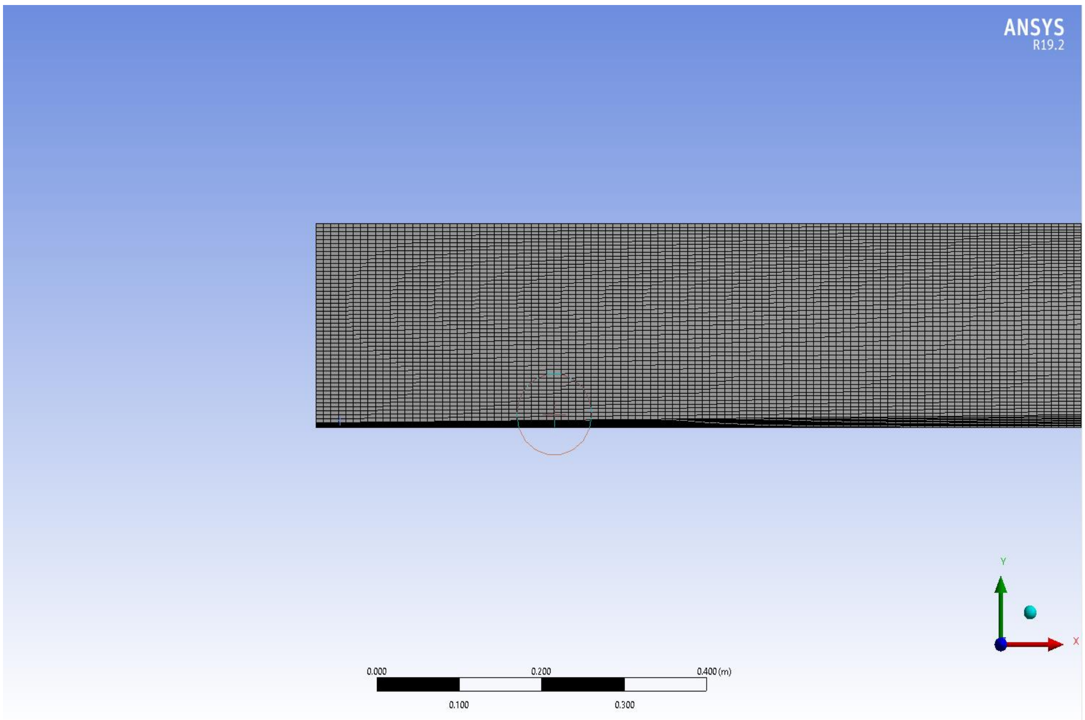

Figure 4.1. Mesh.

As is shown in Fig. 4.1, Insert face meshing, apply geometry selection generate mesh, create named selection" fuel-inlet", create named selection "Air-inlet", create named selection "Outlet", create named selection "Axis", create named selection "pipe wall", update mesh, change the material to fluid. Third, open setup, put 2D space to Axisymmetric, turn the energy equation to on, change viscous-laminar to k-epsilon(2eqn), turn the species model to species transport, mixture material to fuel-oil-air, and the reactions to volumetric and the interplay of turbulence chemistry and eddy dissipation. Eddy dissipation calculates the response rate. Create/edit in material, using the species dialog box, you may modify the mixture material by adding or removing species as needed.

In boundary conditions, edit air-inlet, put velocity magnitude 0.5 m/s, change intensity and hydraulic diameter specifications, specify turbulent intensity 10% and hydraulic diameter 0.44 m, change mass of O_2 to 0.23. Edit fuel-inlet, put velocity magnitude 80 m/s, change specification method to intensity and hydraulic diameter, specify turbulent intensity at 10% and hydraulic diameter to 0.01 m. Specify the mass fraction of methane to 1. Solution methods, change scheme to coupled and turn on the pseudo transient. It enables the pseudo transient algorithm in coupled pressure-based solver. It adds an unsteady term to the solution equation to improve stability and convergence behavior. Specify the density in solution controls to 0.25. click advanced, turn on the (CH_4, O_2, H_2O, and energy), specify the time scale factor of all of them at 10, then make initialize. Change the length scale method to aggressive, specify number of iterations at 1000 then calculate.

As is shown in the table 1, Edit the outlet, change specification method to intensity and hydraulic diameter, specify backflow turbulent intensity to 10% and backflow hydraulic diameter 0.14 m. Specify the mass fraction of O_2 to 0.23. Edit pipe-wall, change the thermal to temperature.

Table 4.1. Properties Biodiesel/Diesel [71].

Properties	**Diesel**	**VEBD100**
Chemical formula	$C_{13}H_{28}$	$C_{17.99}H_{35.12}O_2$
Density at 15°C (kg/m^3)	883.5	877.04
Kinematic viscosity 40°C (mm²/s)	4.24	4.62
Flash point (°C)	174	170
Upper heating value (kJ/kg)	46105	39593.84
Lower heating value (kJ/kg)	43199	37327.60
Cetane number	54	58.7
Sulfur count (mg/kg)	5.5	1.14
Cold filter clogging point	-13.89	-1
Freezing point (°C)	-15	-2
Ester content %(m/m)	-	96.5
Cloud point (°C)	-6	1
Sulphated ash content	0.0016	-0.005

4.1. Palm Oil Biodiesel Production

The Malaysian economy is strongly supported by the palm oil sector. Through the export of value-added goods made from palm oil to the international market, the palm oil business is crucial in assuring a steady foreign investment flow and revenues. This shows the importance of the palm oil business to the Malaysian economy. In 2008, the palm oil sector contributed around Malaysia Ringgits (MYR) 65.2 billion in exports from Malaysia [72]. In 2008, Malaysian palm oil made a substantial contribution to the world's supply of oils and fats. From the total world output of 160 million metric tons of oil and fats, Malaysia contributed 11.1%, or 17.73 million tons, of palm oil. The Association for Malaysian Palm Oil oversees ensuring that palm oil is produced sustainably in Malaysia. It is anticipated that 18.3 million tons of palm oil would be produced. in Malaysia in 2009, up from 17.73 million tons in 2008.

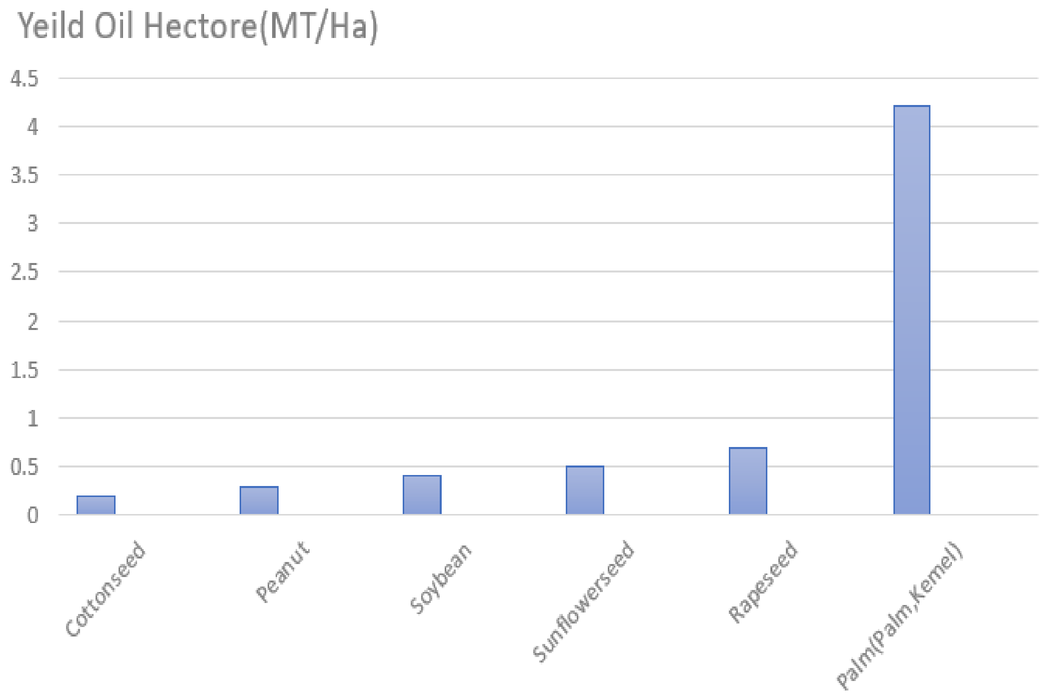

Figure 4.2.Yield Oil Per Hectare at Oilseeds [33].

Rapeseed and soybean oil are only two examples of the sources that are utilized as feedstock for the manufacturing of biodiesel. However, palm oil offers far superior advantages and potential as a feedstock for biodiesel production when compared to other vegetable oils. Unlike soybean and rapeseed, palm oil is a perennial crop. Although yearly production has its periodic upswing and downswing, oil production is continual and unbroken as a perennial crop. When calculating oil output per planted acre, palm plantations produce the most oil. Compared to oil production from soybeans, sunflower, or rapeseeds, palm plantation oil outputs are 10 times greater. According to Fig. 4.2, the production yield of palm oil is higher than that of soybean, sunflower seed, and rapeseed. The amount of palm oil Malaysia imports into the EU is equal to 1.7 million ha of rapeseed or 4.9 million ha of soybeans [73].

4.2. Preparation of biodiesel

Crude Palm Oil (CPO) is the name for palm oil that has been collected and made with palm trees. Transported to a refinery for palm oil, the crude oil is processed there. Refined palm oil, which may be utilized straight as biodiesel or processed into methyl ester, is an industrial product. Another way to create diesel fuel is done by combining petroleum diesel with refined palm oil. Envo Diesel is a type of palm-based diesel that is blended with a particular amount of petroleum diesel. Other than the significant NO emission, which is more than usual, palm oil methyl ester has a good oxidation stability and mild engine emissions [74].

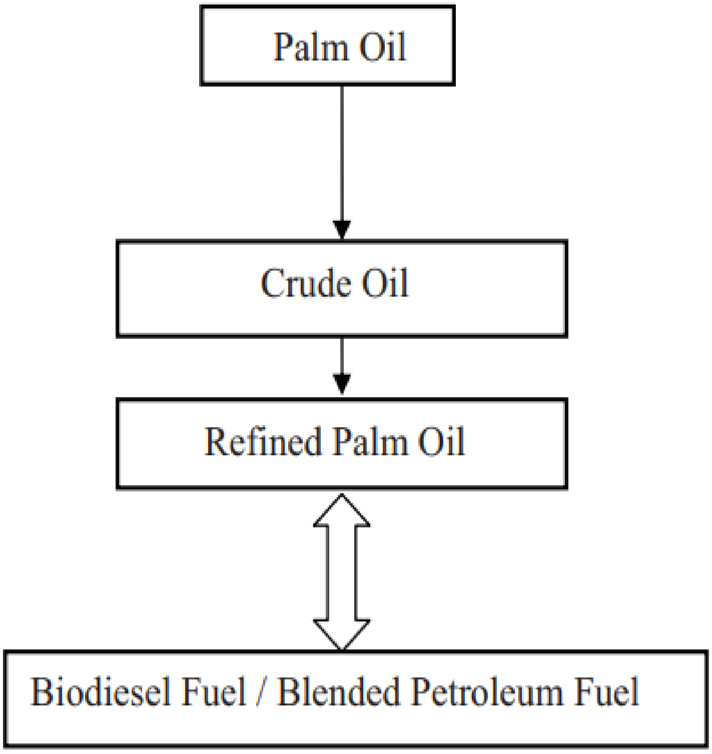

Figure 4.3. Palm Oil Biodiesel Process [33].

Crude and refined palm oils are currently the most widely used vegetable oils available. The nutritious content of palm oil is well recognized, making it a viable choice for use as a vegetable oil in everyday cooking. Elaeis Guineensis is another name for the palm fruit. To extract palm oil, the fleshy, inner wall of the fruit known as the mesocarp must be processed. The conversion crude palm oil, which is subsequently transformed into a variety of goods, such as biodiesel, shown in Fig. 4.3 step by step. The procedures outlined in Fig.4.3 for the refinement and kernel processing of the mesocarp into CPO. The amount of CPO derived from palm trees depends on the kind of palm tree and the age of the tree. You can extract 25–28% of CPO from a bunch of palm trees.

As seen in Fig. 4.3, CPO may be refined to produce refined palm oil, which has a variety of uses, including the biodiesel made from palm oil. As seen in Fig. 4.3, palm oil is converted into refined oil and CPO and finally palm oil biodiesel. Biodiesel made from palm oil may it's converted either becoming methyl ester combined in a certain percentage to fuel-based diesel to create Envo-Diesel. The palm oil biodiesel will be covered in depth in this essay [33].

4.3. Transesterification process

By using the transesterification process, biodiesel is created. The process of transesterification creates esters and glycerol when an oil or fat reacts using alcohol. The graph below depicts the entire chemical process. KOH and methanol, respectively, are the catalyst and alcohol employed for our production processes. Typically, a catalyst is utilized to increase the yield and pace of the reaction [75]. To eliminate the H_2O content, the necessary amount of palm oil was first heated to a temperature of 100^{o}C. Under steady temperature, enough KOH dissolved in methanol was added to the palm oil. The magnetic stirrer was used to stir the mixture constantly at a fixed rpm. The reaction temperature was maintained throughout. The fluid darkens as the process continues, signifying the creation of glycerol [76]. After heating for an hour, the liquid was refrigerated overnight in a separating funnel to allow for layer separation. The bright yellow methyl ester (biodiesel) layer separates high up and the brown glycerol layer separates at the base of the separation funnel after 24 hours. By letting it pass through the funnel's bottom aperture, glycerol was carefully taken out of the separating funnels.

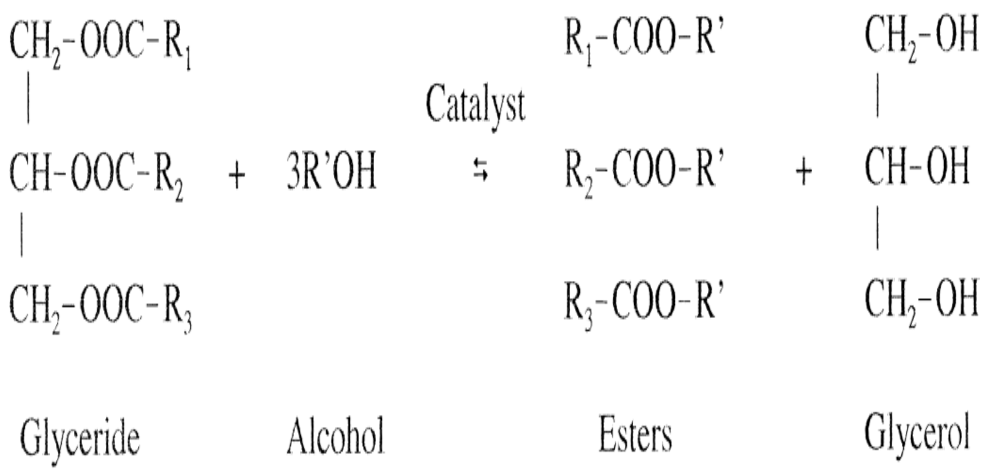

Figure 4.4. Transesterification Operation [33].

As shown in Fig. 4.4, to get rid of the catalyst, alcohol, and other contaminants, the residual product was rinsed in warm H_2O. After being washed, the yield is burned to a temperature of 110°C to eliminate moisture and produce pure biodiesel. The chemical equation above illustrates how palm oil is converted into biodiesel, which also produces glycerin. According to the chemical equation above, glycerin and biodiesel were produced because what transpired between fat or palm short-chain alcohol and oil, represented in the Fig. 4.4, methanol, or ethanol. For instance, the following equation will result in ten kilograms of glycerin and one hundred kilograms of biodiesel when one hundred kilograms of oils react with ten kilograms of alcohol. The conversion process is accelerated with the help of the alcohol. The chains of fatty acids in palmitic oil or fat are shown by R′, R ″, and R‴.

According to the flowchart in Fig. 4.5, there are the following steps in the biodiesel production process.

- Alcohol and the catalyst were combined. With the aid of a typical mixing machine, the catalyst was typically dissolved in the alcohol.
- The palm oil or fat after which the mixture is added, and it is placed into a closed reaction vessel. To stop alcohol from escaping into the atmosphere, the procedure is done in a closed system.

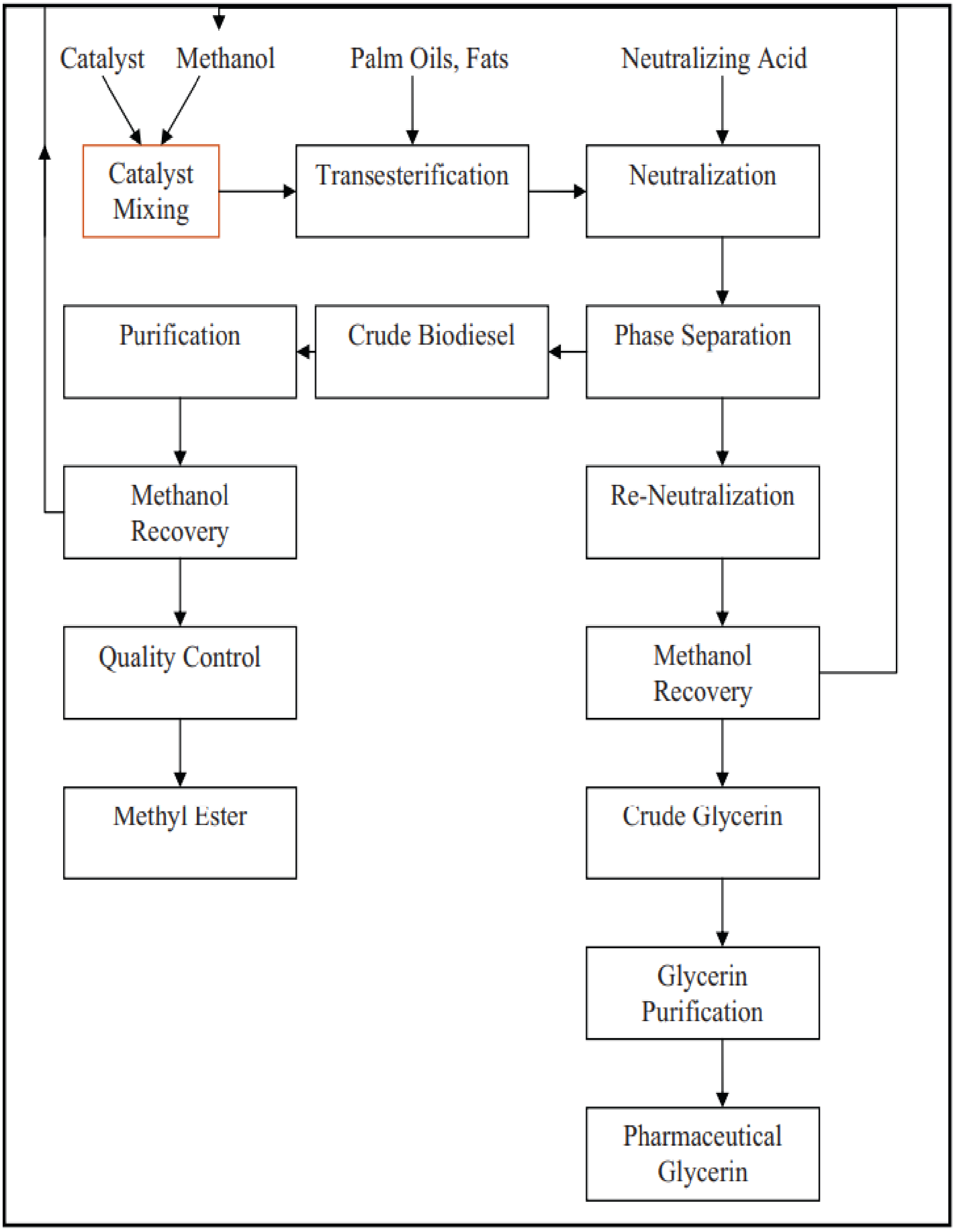

Figure 4.5.Transesterification Process [33].

- For the reaction to occur, the mixture must be maintained at a temperature that is above the alcohol's boiling point, or around 70ºC. The conversion of palm oil into methyl esters can take anywhere between one and eight hours, and extra alcohol is typically employed to ensure this.
- Glycerin and biodiesel will be the two outputs when the reaction is finished.

- The output of glycerin and biodiesel won't be in its purest form. Each will be combined with any leftover alcohol from the previous processes. The neutralizing phase begins at this point. Because glycerin is denser than biodiesel, separating the two outputs is possible by gravity utilizing a draw off the settling tank's bottom.
- The extra alcohol in each will be removed after separating the glycerin and biodiesel, and the mixture will then be neutralized. With the aid of distillation equipment, During the methanol recovery process, the alcohol will be recovered and utilized again.
- The biodiesel is refined further. after separation. This is accomplished using warm H_2O to wash the biodiesel get rid of any kind of foreign material, such as soap or catalyst. Biodiesel is then dried and kept in storage. If the product exhibits properties comparable to Petro diesel viscosity and the hue of the liquid's yellow, distillation can be avoided. By eliminating the liquid's coloring components, biodiesel may be turned colorless in one more phase of distillation.
- The final biodiesel product must be examined using instruments of an international standard to make sure it complies with requirements before being used as an automobile fuel.

PART 5

RESULTS

5.1. Engine Performance

Fig. 5.1 & 5.2 shows that the difference from the chemical formula of the diesel and the Palm Oil Biodiesel. Carbon is found from the beginning of the chemical formula of both fuels, so in this case for sure biodiesel have high quantity of pure carbon than normal diesel. Thanks for CFD simulation the distribution of carbon inside the cylinder is shown clearly, biodiesel have a green color that is higher than diesel.

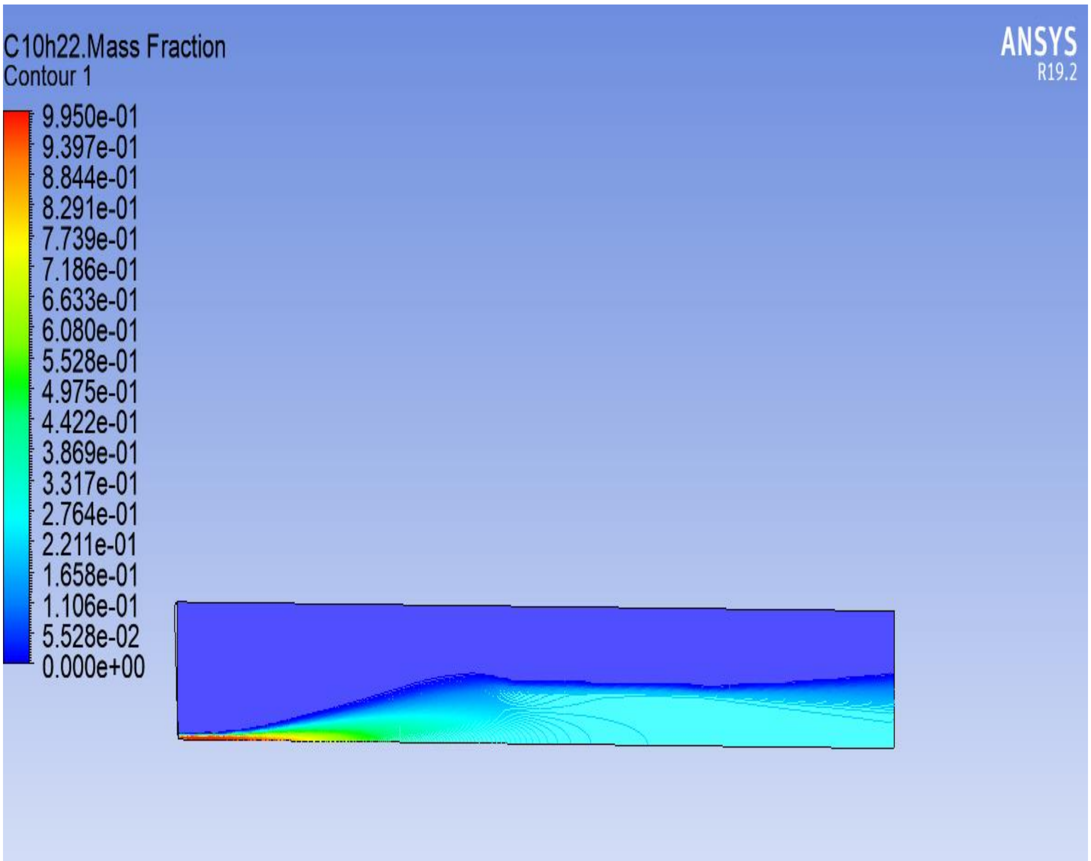

Figure 5.1. Diesel Chemical Formula.

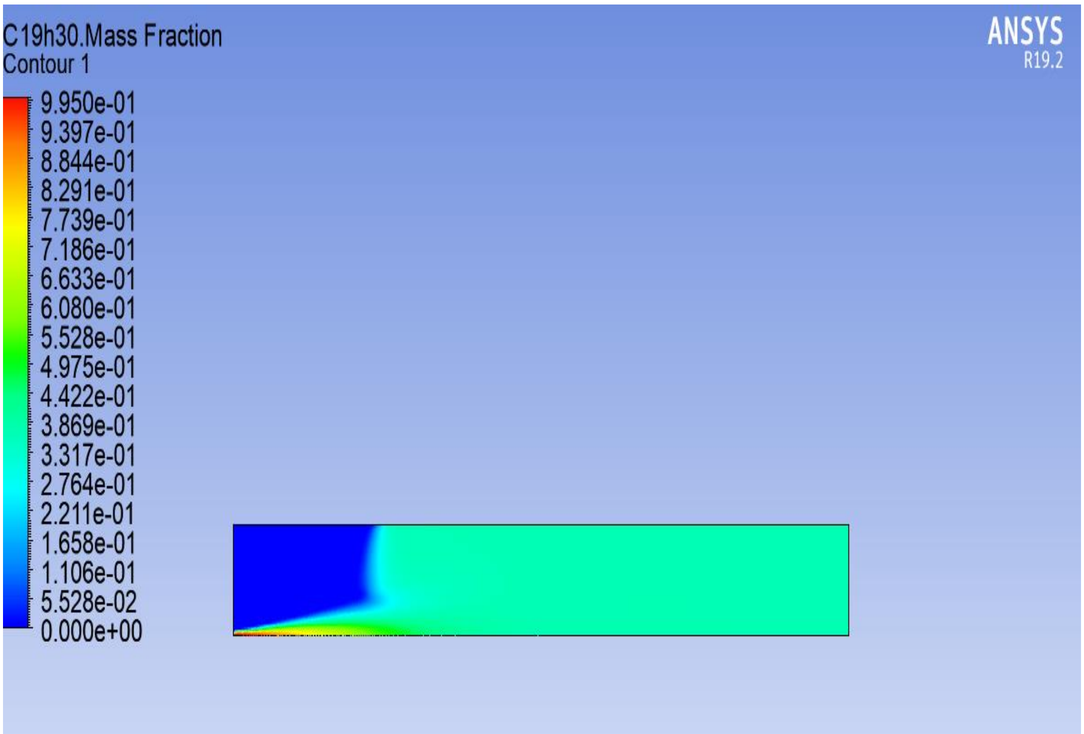

Figure 5.2. Palm Oil Biodiesel Chemical Formula.

Diesel is any liquid fuel that has been particularly created to be used in a diesel engine, a kind of internal combustion engine in which fuel ignition occurs without the need of a spark because of the compression of the input air and the subsequent injection of fuel. Diesel fuel hence requires favorable compression ignition properties. Cetane number is the main indicator of the quality of diesel fuel. A diesel fuel's delay in igniting is gauged by its cetane number. When gasoline is sprayed into hot compressed air, it will ignite more quickly if the cetane number is higher. The minimum cetane number for road diesel in Europe (EN 590 standard) is 51. Some markets provide fuels with higher cetane ratings, which are often "luxury" diesel fuels with extra cleaning agents and some synthetic components [77].

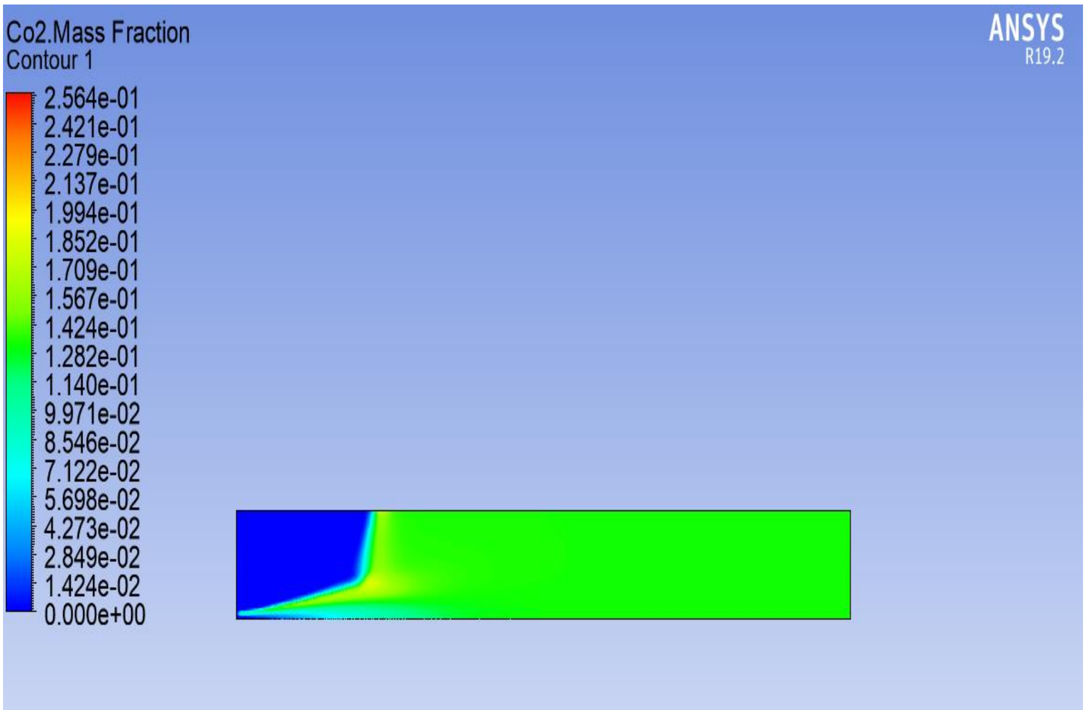

Figure 5.3. CO_2 Mass Fraction On Diesel.

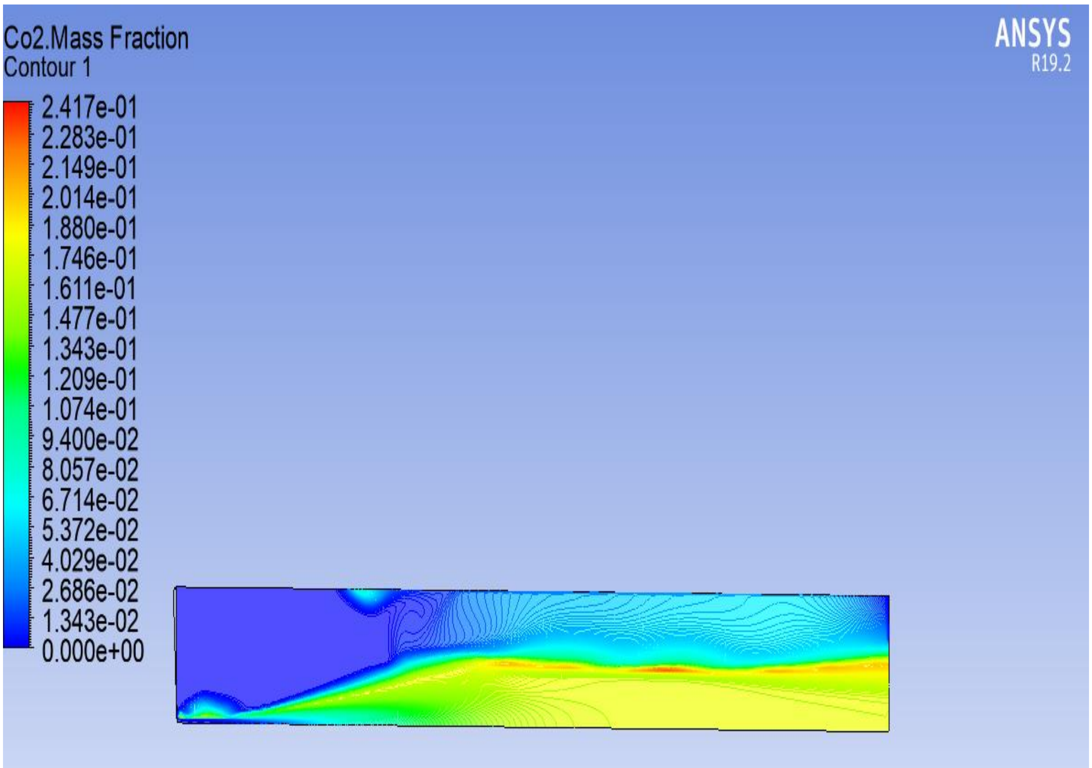

Figure 5.4. CO_2 Mass Fraction On Biodiesel.

As Fig. 5.3 & 5.4 shows the CO_2 mass fraction, Due to higher fuel consumption based on by an increase in engine load, CO_2 emissions increased as well. Compared to diesel oil, all tested biodiesel blends made from algae, palm, and jatropha had lower CO_2 emissions. CO_2 is a chemical substance composed up of molecules with one carbon atom double-bonded covalently to two O_2 atoms in each one of the molecules. At room temperature, it exists as a gas. In the atmosphere, CO_2 serves as a greenhouse gas because it is transparent to visible light but absorbs infrared radiation. The lower CO_2 emissions were attributed to the increased O_2 content of the biodiesel blends made from Jatropha, algae, and palm oil as opposed to diesel. The increased O_2 concentration in WCO biodiesel blends compared to diesel oil was the cause of the rise in CO_2 emissions [78–80]. The mechanisms for CO_2 and CO emissions to originate are diametrically opposed. Even when CO emissions byproducts of insufficient combustion, when combustion is complete, CO_2 is released as opposed to CO. As a result, inside the same situations, CO_2 emissions should rise while CO emissions fall. Vegetable oil biodiesel's high cetane number helped to cut CO emissions. The amount of CO_2 emissions is anticipated to rise [81].

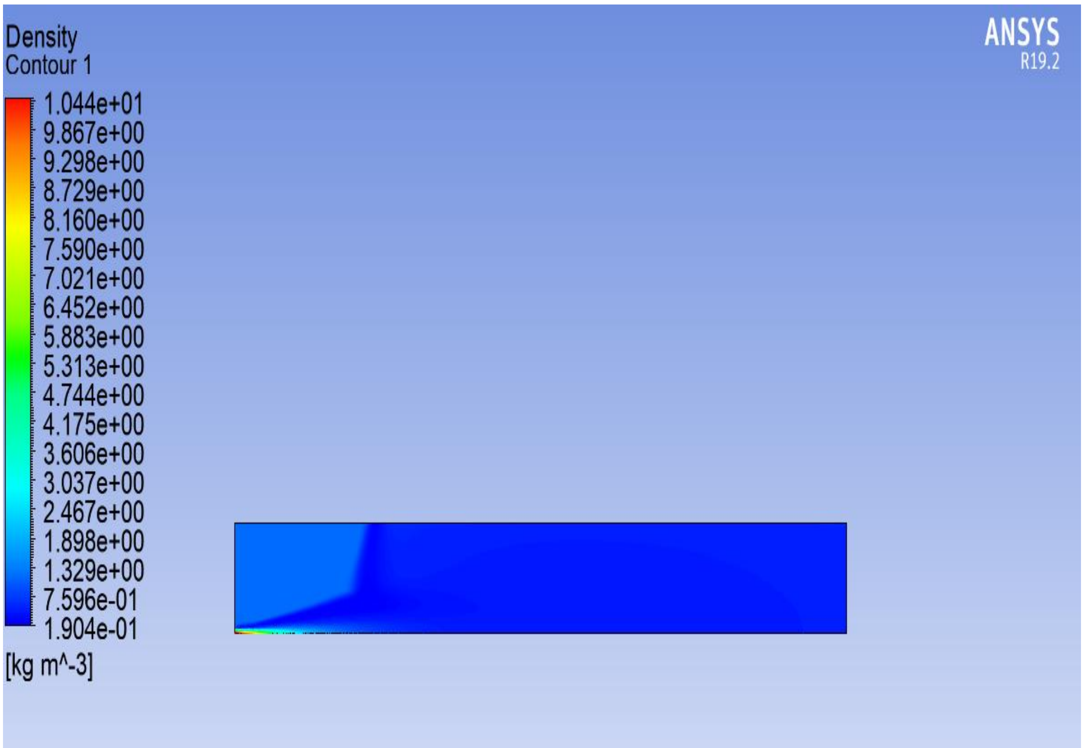

Figure 5.5. Diesel Density.

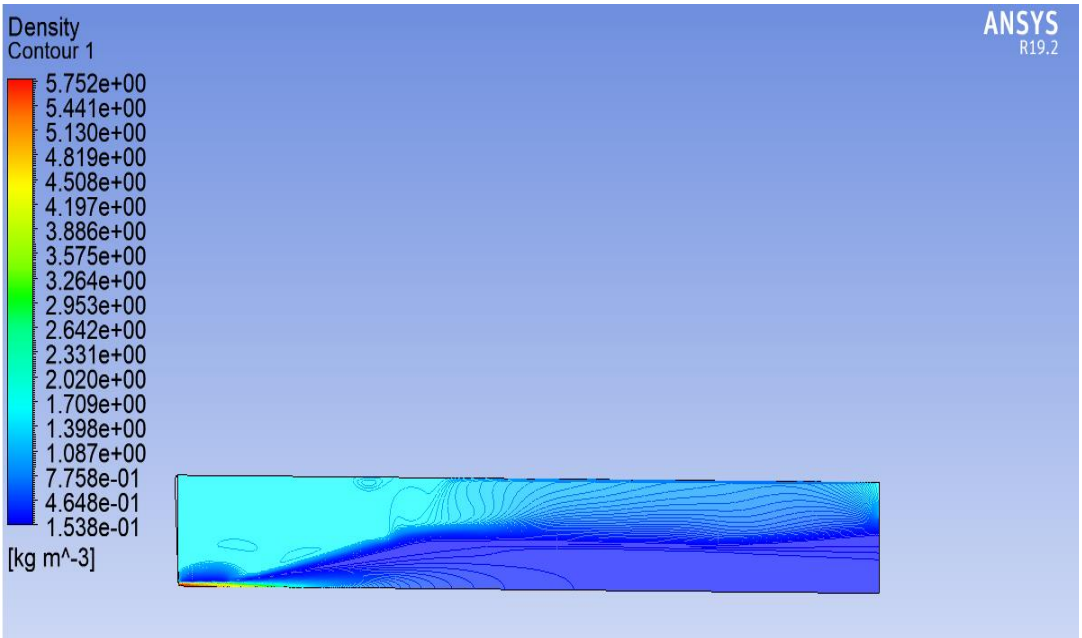

Figure 5.6. Palm Oil Biodiesel Density.

Fig. 5.5 & 5.6 shows the variation of density in diesel and biodiesel. The mass of an item divided by its volume is how density is calculated. Biodiesel typically has a density of 0.86 to 0.90 g/cm^3. Because the densities of methanol and oil are similar to the density of the generated biodiesel, it has been found in many research that the density of biodiesel has not changed much [82,83]. Biodiesel's density is a crucial characteristic for liquid fuel. Volumetric flow is often used to assess the fuel's delivery from the fuel tank to the engine, whereas weight-based calculations are used to determine the energy released in the combustion chamber. The density serves as a link between these two characteristics. Additionally, calculations for storage facilities, fluid flow, distillation units, separation processes, storage tanks, reactor design, and process piping all call for density data. The density of the biodiesels produced for this research fall in this range. Waste Palm Oil Biodiesel (WPOB) has the lowest density out of all the biodiesels, while the densities of the rest are quite comparable. Compared to biodiesels, diesel fuels have lower densities. Although biodiesel has a far higher density than diesel fuel, it has a lower energy content both in terms of mass and volume [84]. In my experiment, the Fig 5.5 & 5.6. shows that the biodiesel density is higher than the diesel density in range of 0.85 to 0.925. As we observed that biodiesel’s density has not changed a lot.

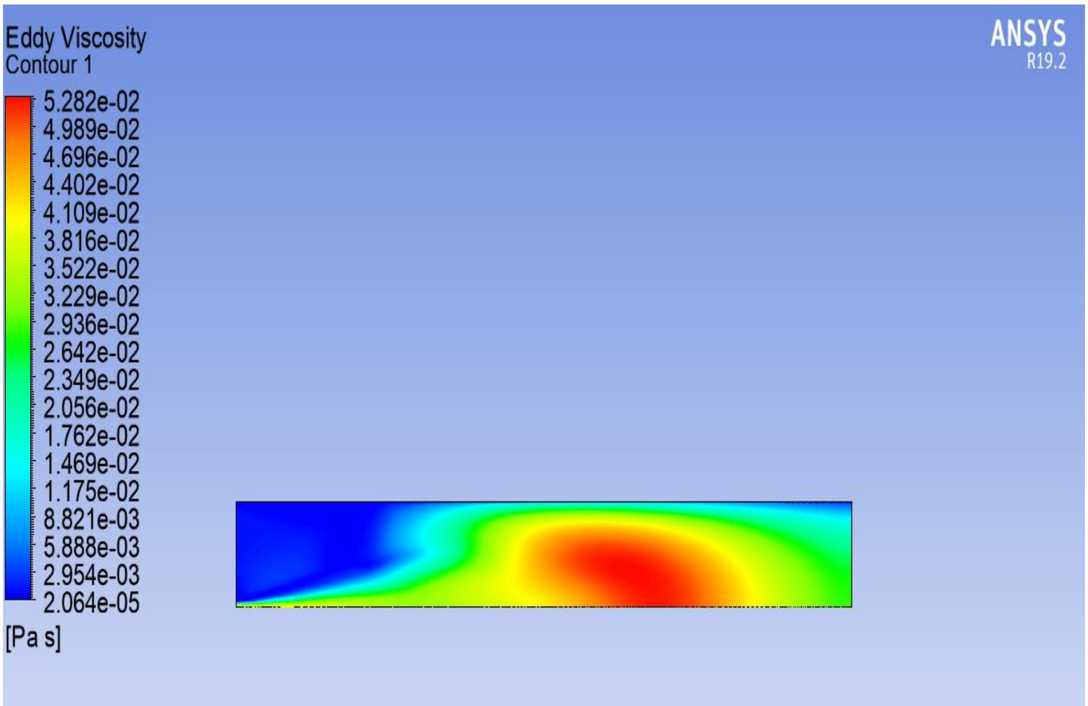

Figure 5.7. Viscosity For Diesel.

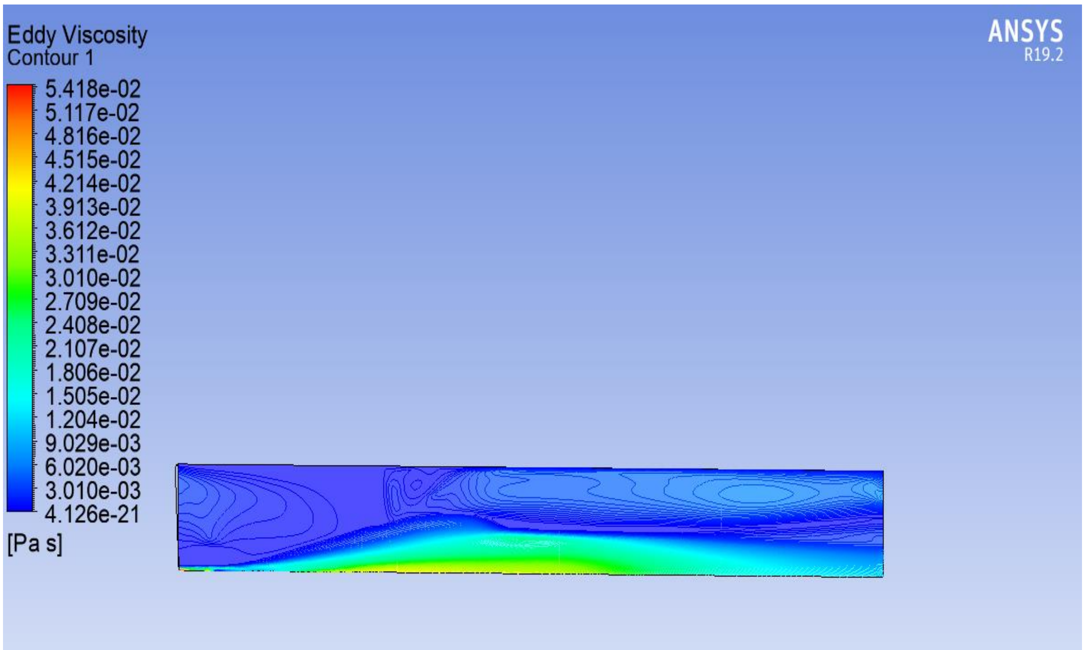

Figure 5.8. Viscosity For Biodiesel.

As is shown in Fig. 5.7 & 5.8 the variation of eddy viscosity in diesel and biodiesel, compared to diesel, palm oil biodiesel has a greater viscosity., thanks for CFD that we can clearly noticed the variation of the viscosity and how it is being higher in the biodiesel. Viscosity is one of the most crucial characteristics of petroleum-based fuels, including biodiesel and conventional diesel This is a crucial characteristic of lubricants. Various biodiesel and petro diesel standards specify the permissible kinematic viscosity ranges. In a fatty ester or an aliphatic HC, the chain length of the fatty acid or alcohol component causes an increase in kinematic viscosity. Aliphatic HC have a lower rise in kinematic viscosity over a specific number of carbons than do fatty molecules. As a measure of a substance's flowability, viscosity is an important factor of any fuel. Since there is a relationship between the ester content also viscosity the ester level decreases as viscosity increases. this metric is also helpful for assessing the methyl and ethyl ester concentrations of biodiesel samples [85]. Because biodiesel has a greater viscosity than diesel, biodiesel-diesel blends offer a substitute to enhance this characteristic of the biofuel. Additionally, the fatty acid profile of the biodiesel affects its viscosity. Blends of biodiesel from various sources can thus be used to lower viscosity to the necessary levels [86].

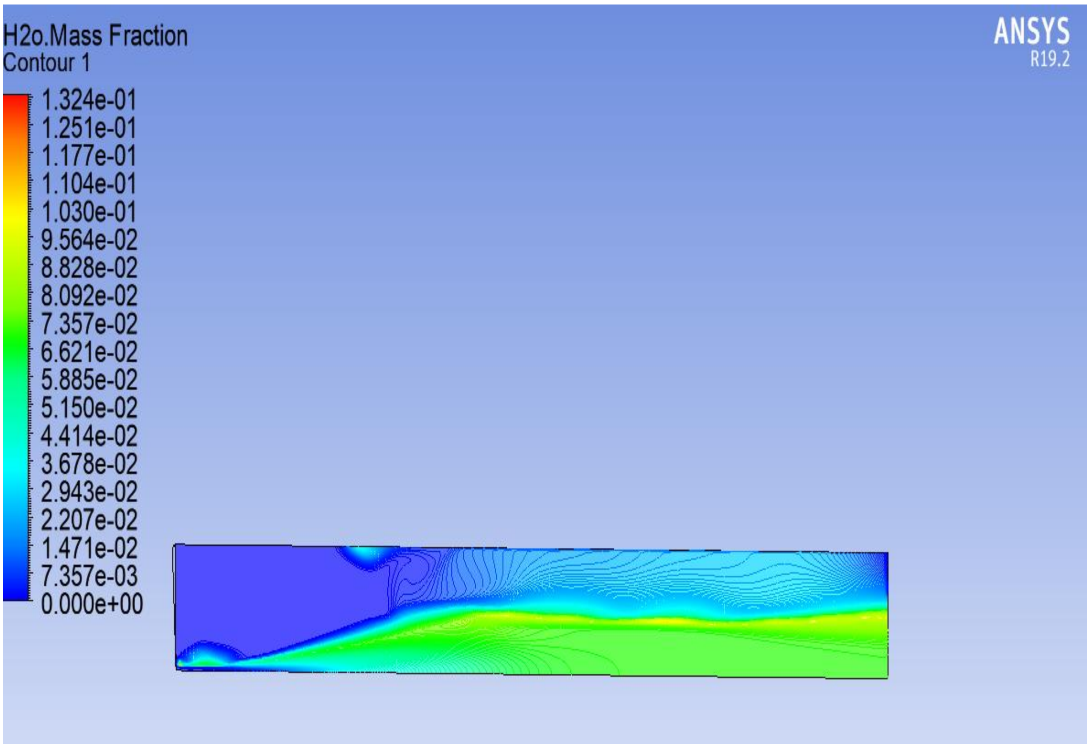

Figure 5.9. H_2O Mass Fraction for Diesel.

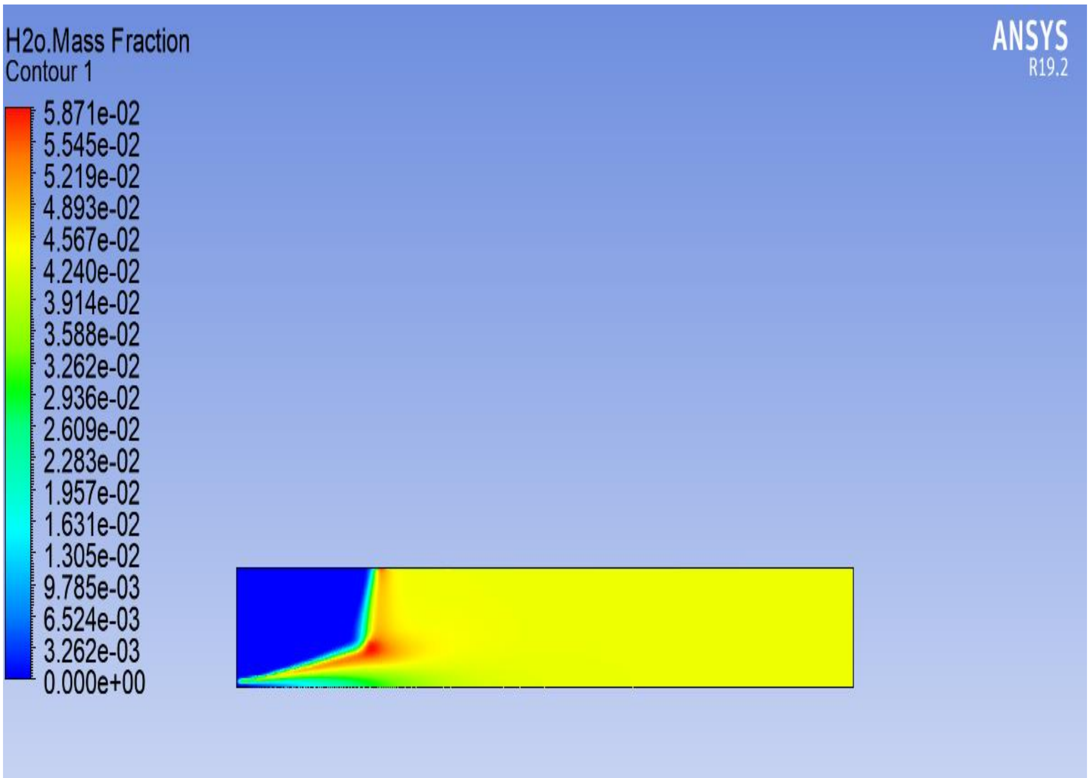

Figure 5.10. H_2O Mass Fraction For Biodiesel.

Fig. 5.9 & 5.10 shows that the variation of the H_20 mass fraction of the diesel and the Palm Oil Biodiesel. H_20 in the biodiesel is higher than diesel, because it contains O_2 in chemical formula and thanks for CFD simulation the distribution of H_2O in the cylinder is shown clearly and noticed which one is highest depending on colors, Biodiesel is higher than diesel since it has yellow and red color not like diesel blue and green. It is well knowledge that in the synthesis of biodiesel, the vegetable oils or fats utilized as a raw material for the transesterification should be H_2O free since the presence of H_2O impairs the reaction. H_2O can chip away at the catalyst, decreasing its effectiveness. The unfavorable impact of H_2O is larger than that of free fatty acids. Given that waste vegetable oils and crude oils typically include H_2O and free fatty acids, these issues could make it more difficult to use them as effectively as possible. The yield of methyl esters by supercritical methanol treatment was explored in the current study, and the yields were compared with those from alkaline and acid catalyzed techniques, due to the significant influence of H_2O and fatty acids on the transesterification reaction. Additionally, research was done on how H_2O affected fatty acid methyl esterification [87].

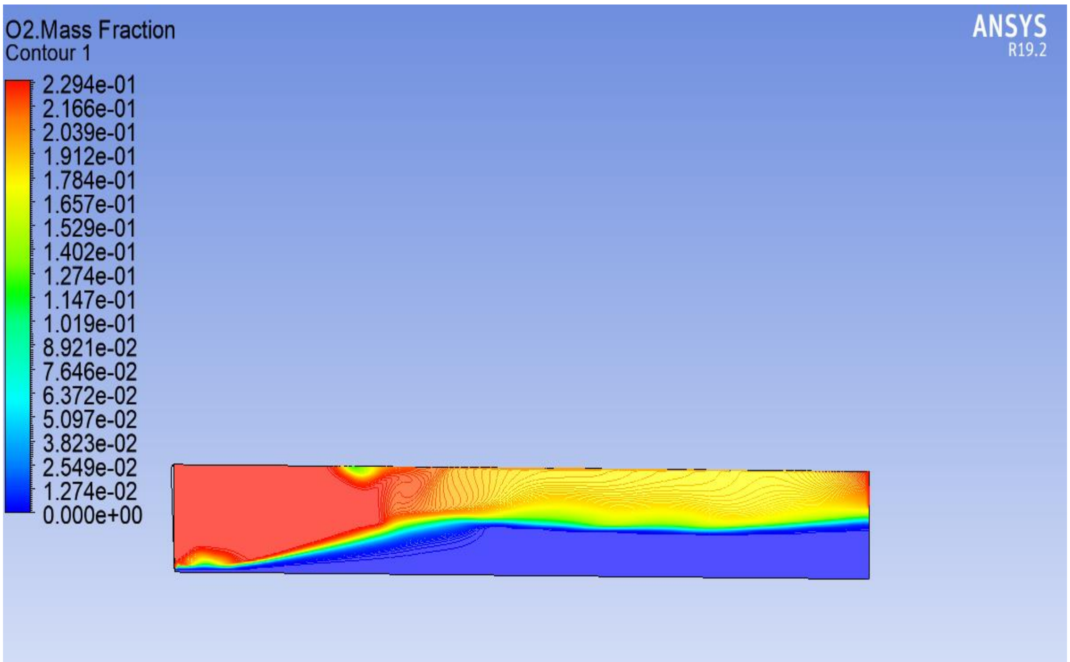

Figure 5.11. O_2 Mass Fraction In Diesel.

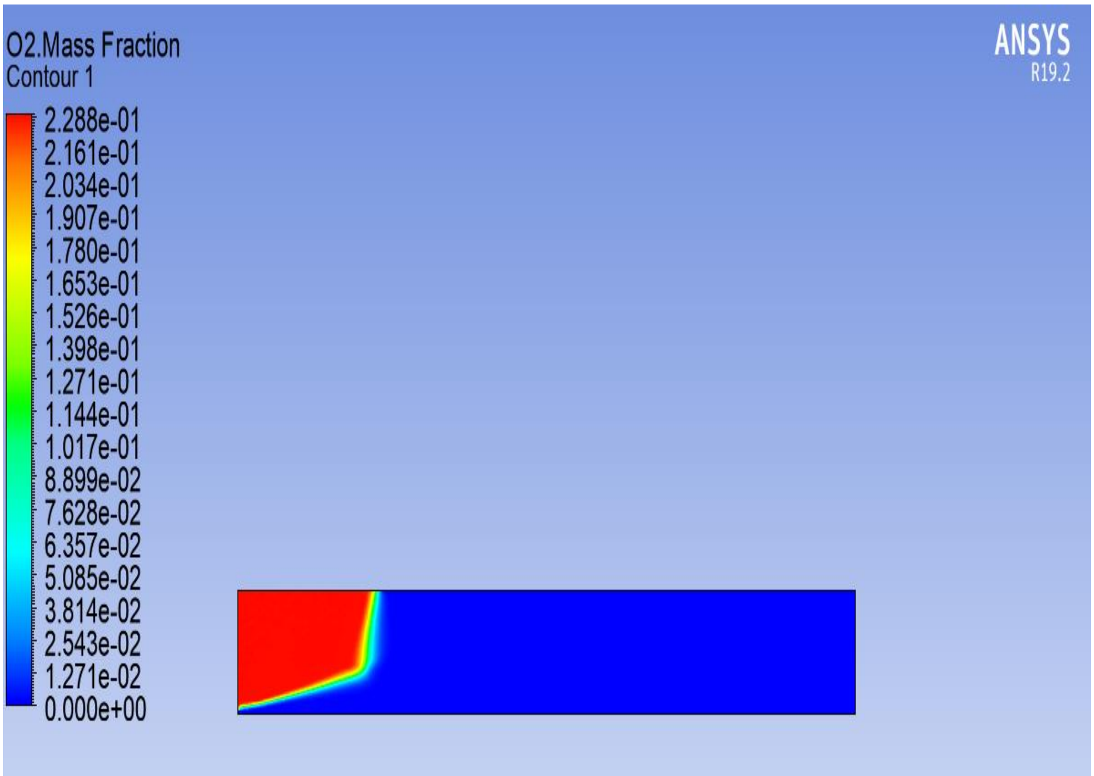

Figure 5.12. O_2 Mass Fraction In Biodiesel.

As is shown in Fig. 5.11 & 5.12, the O_2 is founded from the beginning inside the chemical formula of vegetable palm oil biodiesel. So, in this case for sure the biodiesel will have a high quantity of pure O_2 than normal diesel. and thanks to the CFD simulation the distribution at O_2 inside the cylinder is shown clearly. A diesel engine operates optimally within a specific range of fuel O_2 concentration when considering both performance parameters and emission characteristics. This is true for all types of biofuels, including pure biodiesel, biodiesel mixtures, and blends of biodiesel and petroleum diesel. The O_2 concentration is determined to be between 1.8 and 3%. The variances in each engine performance and exhaust emissions parameter are determined to be 3% in this range of O_2 content. Because of how it is made, biodiesel contains O_2. Anaerobic processes are used for the lengthy production of petro diesel. Because of these circumstances, dead plant and animal matter loses its O_2 content, leaving only carbon and hydrogen to create petroleum and other fossil. A fuel's ability to burn has a lot to do with how much O_2 it contains. Therefore, seven mixes with various O_2 contents from the solubility zones were used to assess its impact on exhaust emissions [88].

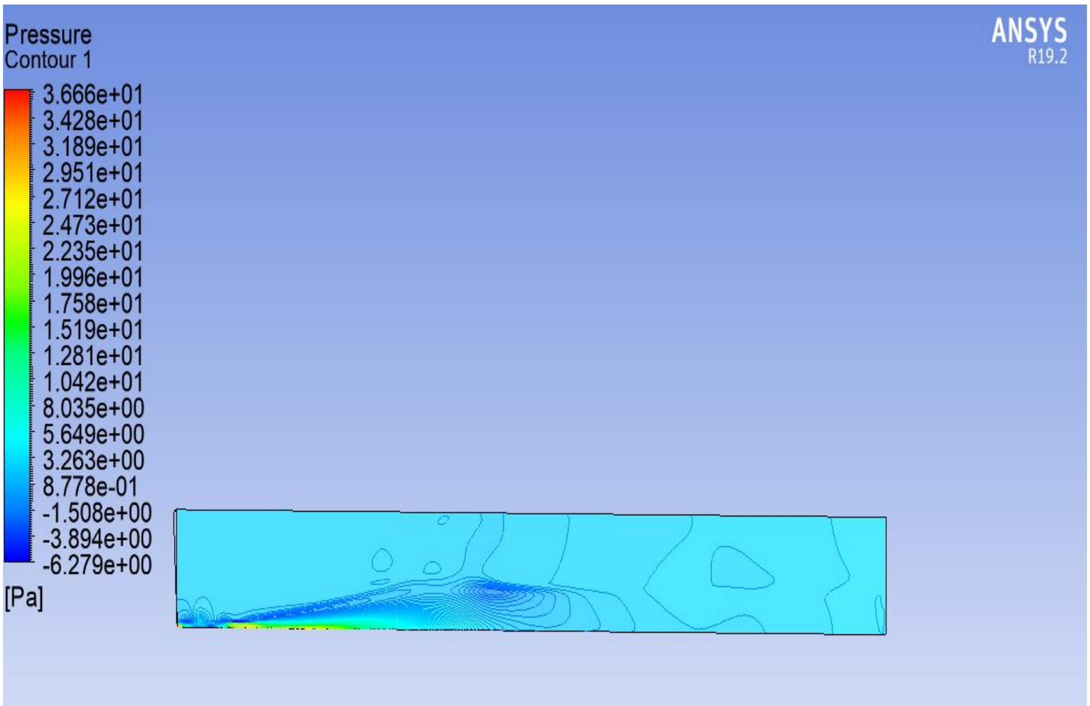

Figure 5.13. Diesel Pressure.

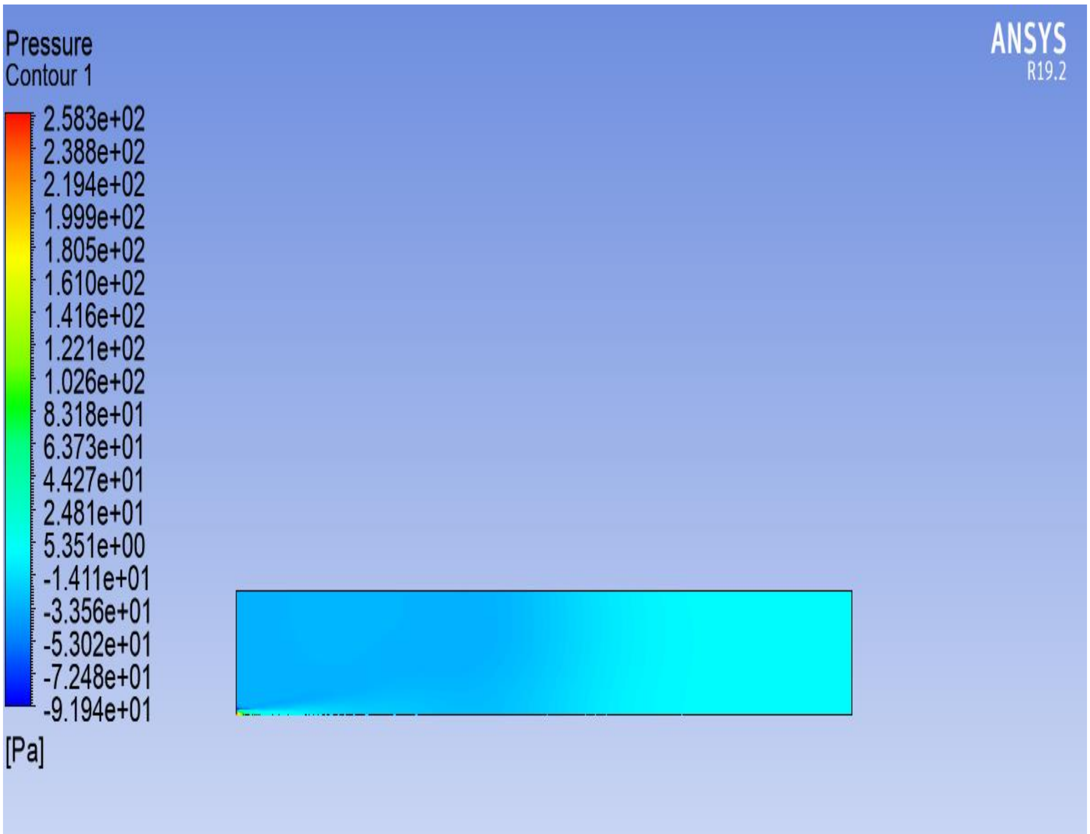

Figure 5.14. Palm Oil Biodiesel Pressure.

As is shown in Fig. 5.13 & 5.14, the pressure result in biodiesel is higher than diesel. Due to the high number of cetane in alternative fuel. This will lead to an elevation in the pressure of the cylinder. The differences in cylinder pressure for diesel and biodiesel at various engine loads as a function of crank angle. At lower engine loads, it is obvious that biodiesel has a larger peak cylinder pressure than diesel, but at higher engine loads, they are nearly comparable for both fuels. The in-cylinder pressure, which is controlled by ignition delay and combustion mixture, is the pressure that develops inside the combustion chamber during one stroke of engine operation. The operating circumstances and fuel input components have an impact on the premixed combustion stage's rate of combustion, which determines the peak cylinder pressure. Biodiesel combustion begins earlier than diesel combustion at all engine loads. This is because biodiesel has a quick ignition delay and accelerated injection timing (because of a higher bulk modulus and higher density of biodiesel) [89]. Due to the high O_2 concentration in biodiesel molecules, which causes a rise in the rate of combustion, peak temperature, and pressure, all biodiesel fuels have greater peak pressures than diesel fuel. The percentage of fuel that burns during the premixed phase and the fuel's capacity to mix properly with air are the key determinants of cylinder pressure [90].

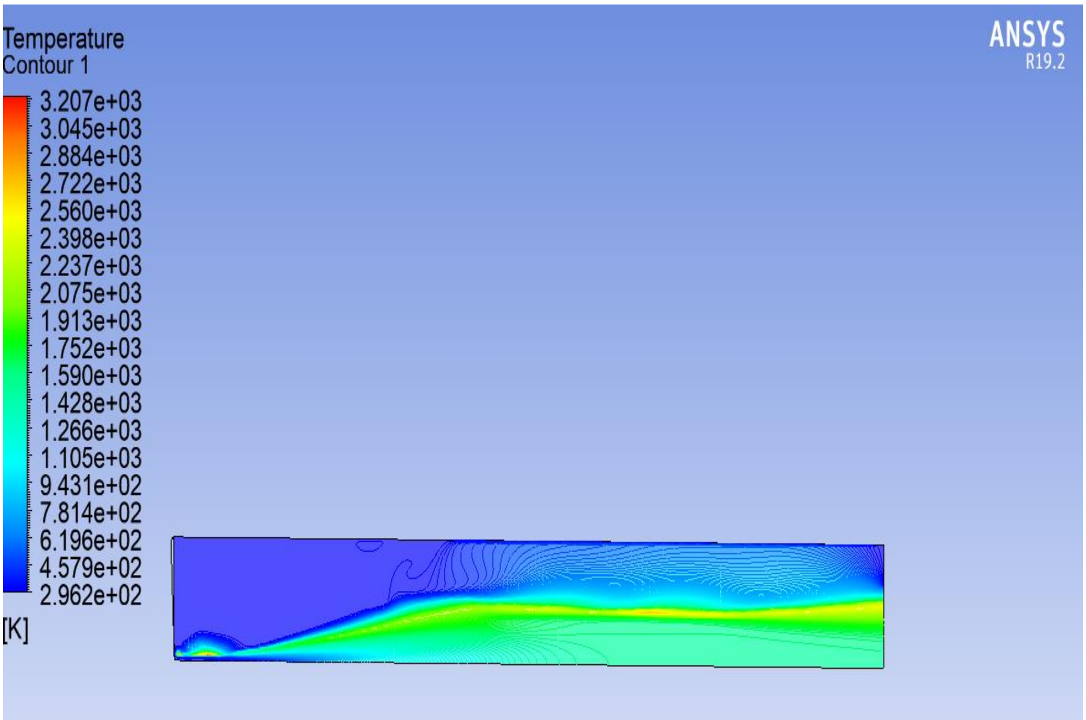

Figure 5.15. Temperature in Diesel.

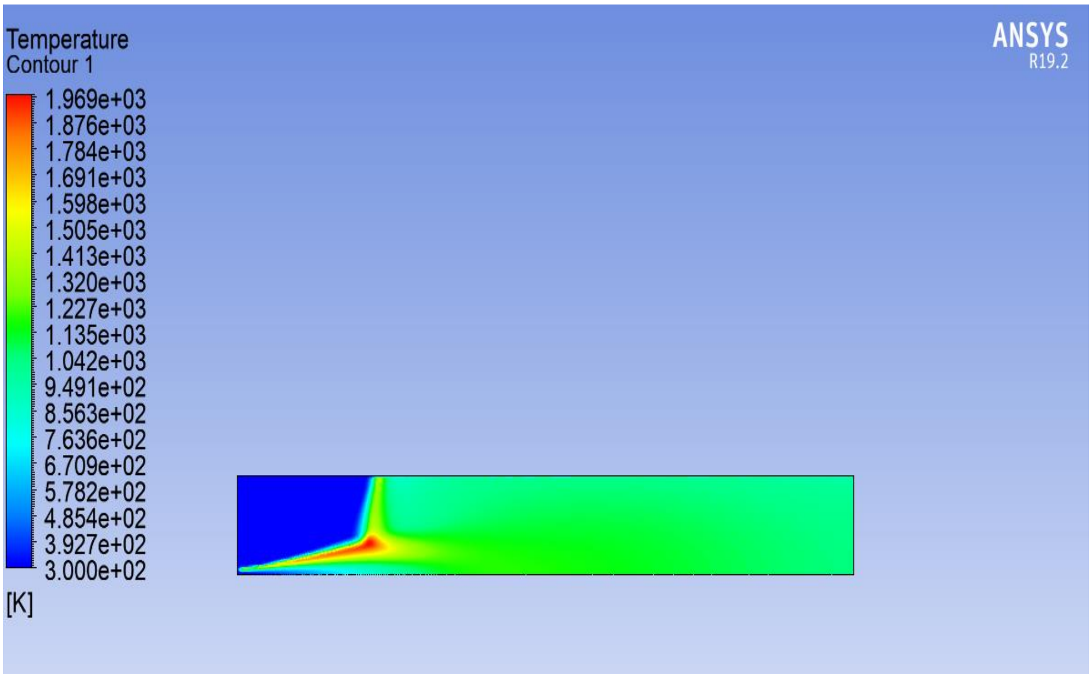

Figure 5.16. Temperature in Palm Oil Biodiesel.

As is shown in Fig. 5.15 & 5.16 the temperature in biodiesel is higher than in diesel. Due to the high number of cetane in the palm oil biodiesel and thanks to CFD we can notice the raise of the temperature from the contour. The temperature of the transesterification reaction is one of the factors that must be managed since it will impact the yields of biodiesel and determine how quickly the reaction proceeds. To stop the alcohol from evaporating, the reaction temperature must be lower than the alcohol's boiling point. The output of biodiesel will increase as the reaction temperature rises. The high yield is a result of the reactant molecules moving more quickly. The kinematic viscosity of the biodiesel sample decreases as temperature rises. The kinematic viscosities of the biodiesel sample change dramatically with temperature when the temperature is low. For all fuels, the temperature of the exhaust gas rises as the engine load rises. Heat loss in exhaust fumes and fuel usage increased because of biodiesel blends decreased thermal efficiency relative to diesel fuel. The increase in cylinder temperature as more gasoline is used inside the engine might be the cause of the trend. With an increase in engine load, there was a greater heat loss in exhaust gases. When comparing biodiesel blends to fossil fuel for the whole engine load, higher exhaust gas temperatures were observed.

5.2. BTE Results

Based on engine load, Fig. 5.21 compares the BTE curves for all test fuels. The actual brake effort per cycle divided by the amount of fuel chemical energy yields the brake thermal efficiency. When the graph is examined, BTE levels show a general decline with the usage of palm oil biodiesel. P20 gasoline produced the greatest BTE value at the (750–1000 w) engine load. At 50% and 100% load, biodiesel's BTE was discovered to be somewhat greater than diesels, while the reverse result was seen at 25% load. In terms of combustion properties, biodiesel was found to have a somewhat shorter ignition delay and a lower peak heat release rate than pure diesel.

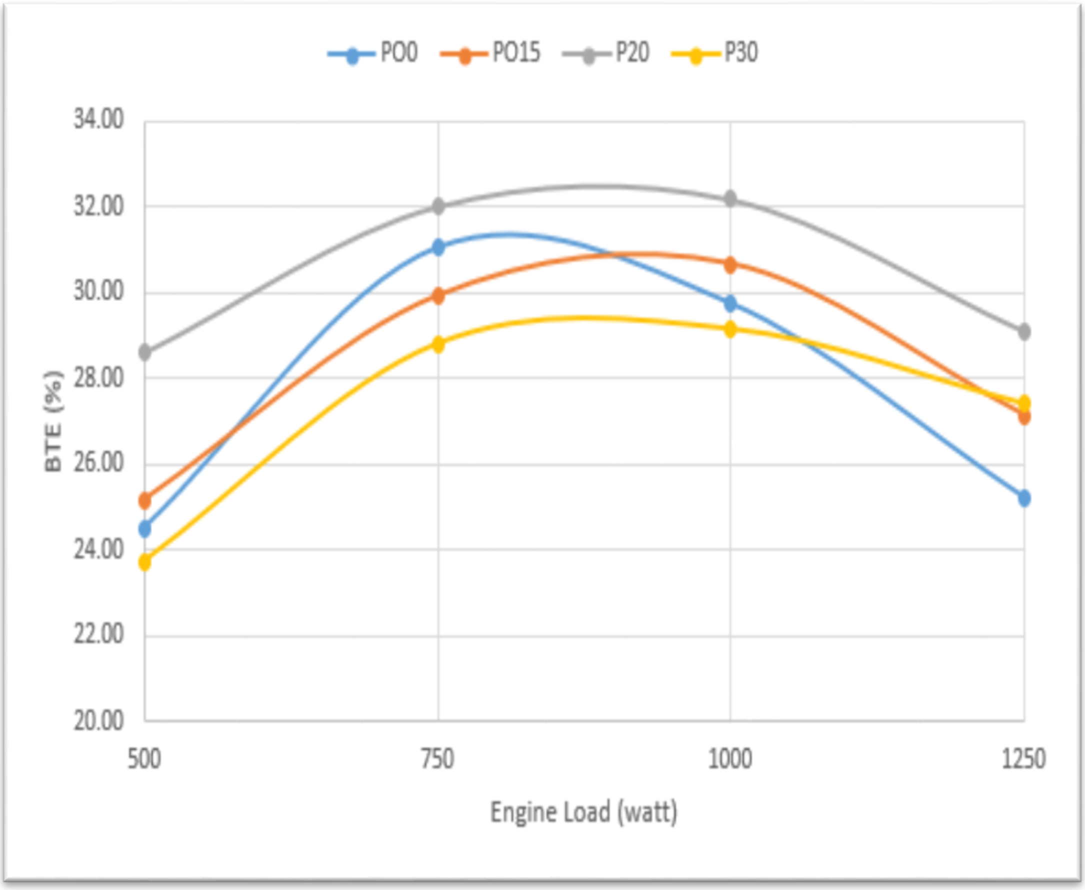

Figure 5.17. BTE with Respect To Engine Load.

BTE readings increased once again as the mixture's viscosity fell as the ratio increased because vegetable biodiesel (VEBD) has a viscosity that is like that of diesel, and it provided findings for BTE that were like those of diesel. Higher viscosity, poor spray properties, and reduced calorific value were the causes of the decreased BTE with biodiesel mixes. The greater viscosity results in less efficient atomization, vaporization, and burning of the fuel, which lowers the thermal efficiency of the biodiesel mixes compared to diesel. The thickness of the oil and the quantity of energy produced by the biodiesel had replaced the O_2 content in biodiesel as a dominant criterion as the biodiesel concentration increased. Increased engine load translates to high cylinder pressure and temperature. High combustion efficiency is seen from the cylinder's high temperature and pressure. As a result, the change in engine load directly affects BTE. Instead, it is evident that when the load on the engine rises, all fuels' BTE values grow when engine load is considered while analyzing the BTE curves. With an increase in the amount of biofuel being blended, there was a tendency toward increased viscosity and decreased calorific content. The BTE value increased along with the load because a better combustion is made possible by the extreme heat produced within the larger load on the cylinder [71].

5.3. BSFC Results

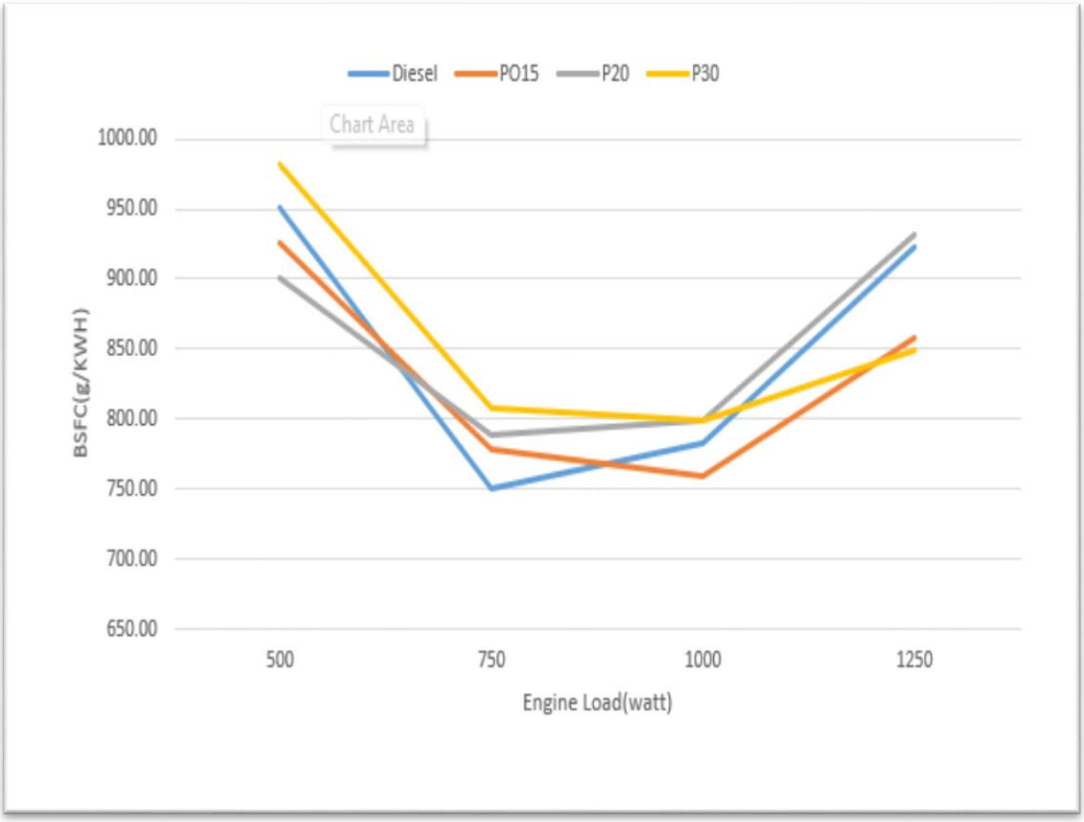

Figure 5.18. BSFC with Respect To Engine Load.

Based on engine load, Fig. 5.18 compares the BSFC curves for all test fuels. More fuel must be utilized when utilizing fuels with low thermal values to provide the engine an output power that is like using diesel fuel. Specific fuel consumption is a crucial factor when assessing engine performance. The efficiency of energy conversion increases as this value decreases. To generate the same amount of braking power, more gasoline must be delivered, increasing BSFC. The engine load is regarded as the factor that has the greatest impact on the BSFC. This was caused by the dominance of reduced calorific value relative to O_2 content, which required more fuel to create the same amount of power as diesel fuel. The rate of incomplete combustion is decreased and the BSFC falls with rising in-cylinder temperature and engine load. On the other hand, if the load is reduced, the temperature within the cylinder drops and there is more incomplete combustion. The BSFC values rose at the minimum load (500 W) and at the highest load (above 1000-1250 w), as shown in Fig. 5.18, since the palm oil biodiesel has lower thermal values than diesel. Greater BSFC values were also a result of biodiesel fuels' higher density. As opposed to that, when engine load grew, the BSFC values of all fuels tending to decline. As the load increases, increasing the cylinder temperature enhances fuel combustion and lowers missed combustion loss, which decreases BSFC. BSFC values were calculated using PD0 (Diesel), PO15, PO20, and PO30 [71].

5.4. HC emissions

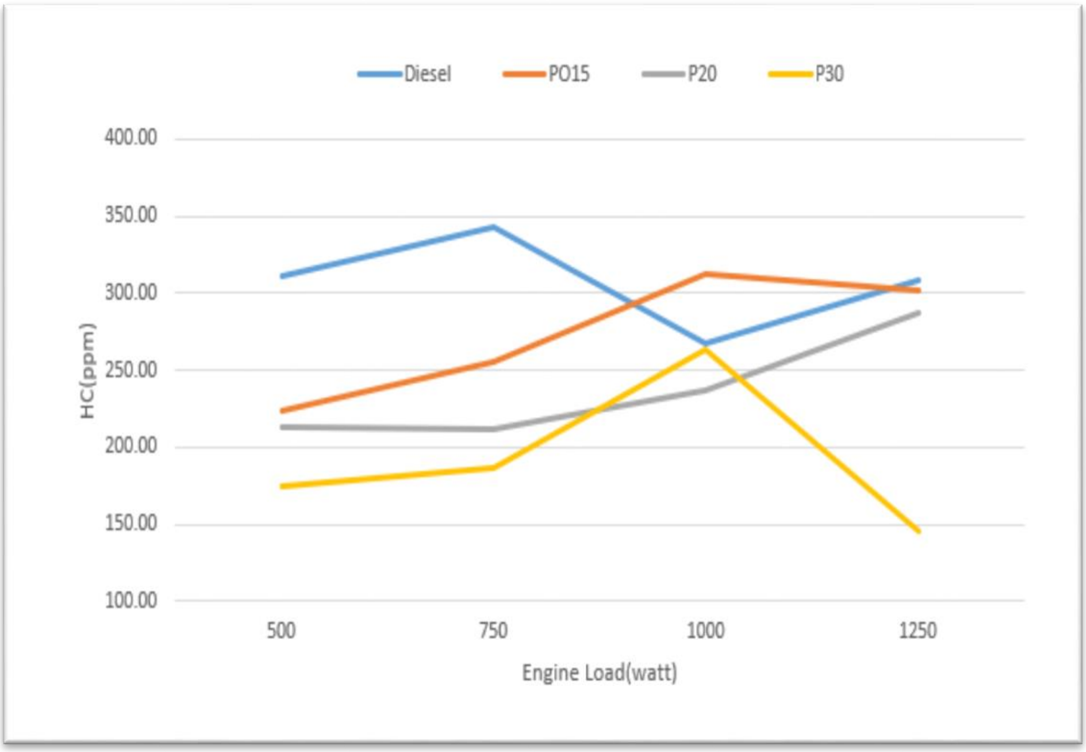

Figure 5.19. HC with Respect To Engine Load.

HC is compared with engine load in Fig. 5.19. Incomplete combustion results in both HC and CO emissions. The fuel that was put into the cylinder via injection. has left the absence of combustion in the engine when there are HC emissions in the exhaust gas. Little O_2 levels cause HC emissions to occur regions of the cylinder. With an increase in load, the unburned HC output progressively rises. This is because heavier loads require more fuel injection. Fig. 5.19 displays the levels of HC emissions brought on by variations in engine load for four distinct fuels. Due to the increased Cetane ratings in relation to diesel, the amount of HC emissions measured from all fuel combinations usually contains biodiesel were low. HC emission as compared to pure diesel fuel. The amount of O_2 in the air-fuel combination has reduced because of the engine load, and O_2 deficiency has increased the amount of HC emissions, because the higher engine load will result in more gasoline being injected. Increases in HC emissions were less in fuels containing biodiesel than in diesel because of the O_2 content of biodiesel. This is because biodiesel, which includes more O_2 atoms, burns completely and steadily. According to Fig. 5.19, which compares the BSFC curves for all test fuels depending on engine load, the reason the HC emissions are low is because it has a lower viscosity value than the other biodiesel [71].

5.5. CO emissions

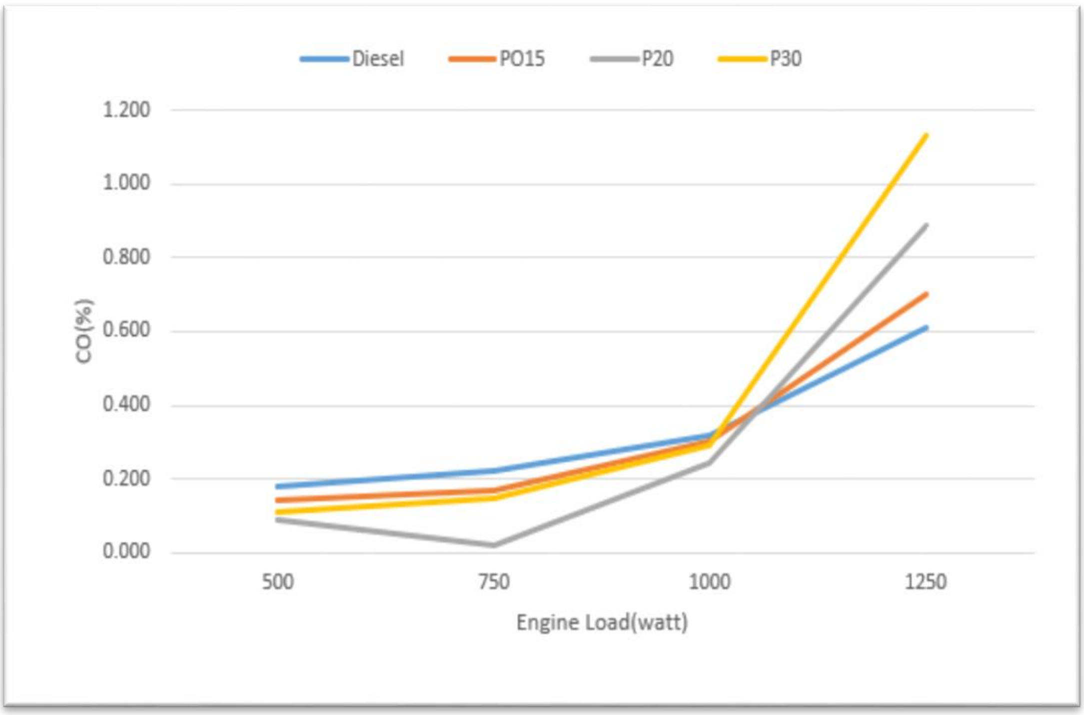

Figure 5.20. CO with Respect To Engine Load.

Fig. 5.20 shows the CO emission curves that were produced by evaluating four different fuels at various engine loads. When utilized at low loads, nearly all fuels provide CO emission levels that are quite comparable. CO levels begin to vary when the engine load hits 1000-W. The PO15 produced the most CO emission at 1250-W, the highest engine load value measured during the testing, while Diesel produced the lowest CO emission. CO emission levels rise with the usage of palm oil diesel. Instead of CO_2, carbon atoms are released as CO from the exhaust. A drop in injection pressure causes an increase in CO emission. Since there isn't enough O_2, making CO emissions a byproduct of incomplete combustion. Diesel engine combustion is facilitated by high cetane index fuel. When high cetane fuels are utilized, the amount of full combustion rises and the rate of partial combustion falls. Because of the lack of O_2, carbon atoms are expelled from the exhaust as CO rather than CO_2, making CO emissions an incomplete combustion product. High cetane index is a characteristic that enhances combustion in diesel engines. The amount of complete combustion increases, and the rate of partial combustion reduces when high cetane fuels are used. Full combustion response reduces CO emissions.CO emissions are decreased via a full combustion reaction. Since VEBD has a significantly a fuel with a higher cetane grade than diesel, utilizing it lowers CO emissions. A characteristic known as the engine load affects the temperature and pressure inside the cylinder as well as the missed combustion rate as it increases. Up to medium engine load values, CO emission values rose in all fuels; nevertheless, at high engine loads, they rose once again [71].

5.6. NO_x Emissions

Fig. 5.21 displays the NO_x levels for the four different test fuels as they change with the engine load. Internal combustion engines need O_2 to burn the fuel, which is found in the air's 21% O_2 concentration. About 79% of the remaining air is composed primarily of N_2. High temperatures and pressures inside the cylinder cause a reaction between N_2 and O2 that results in NO_x emissions.

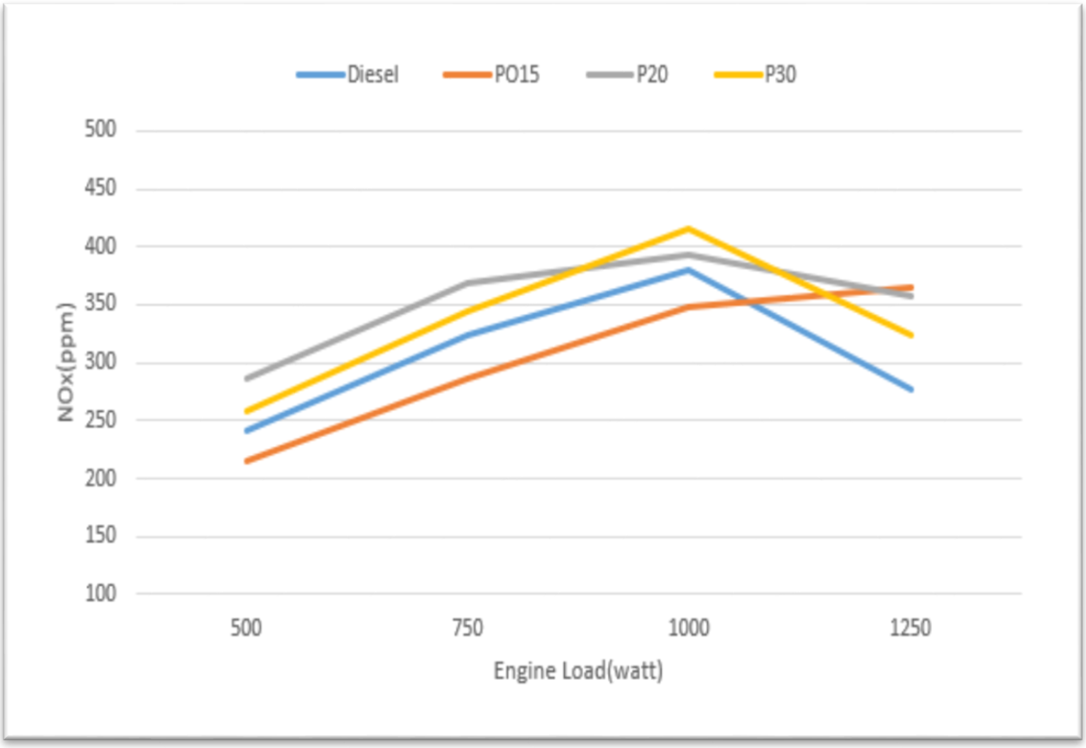

Figure 5.21. NO_x with Respect to Engine Load.

It is well known that cylinder temperature increases along with engine load. Therefore, it is predicted that when engine load rises, all test fuels would emit greater NO_x. In fact, Fig. 5.21 supports this assertion. The chemistry of the fuel as well as high temperatures and pressures have a role in the production of NO_x emissions. Due to the fuel's high density, there will be more fuel in the combustion chamber, because of the increased regional temperatures, this increases NO_x emissions. It is well known that high temperatures are when NO_x emissions are most common. As a result, it is anticipated that a parameter changing the cylinder's temperature will have a significant influence on how NO_x emissions vary. The engine load has a surprising impact on NO_x since it is a factor that raises the temperature within the cylinder as it grows. Additionally, because of the high fuel aromatic content, the adiabatic flame's temperature increases, increasing NO_x emissions. Because there is so much O_2 present, more N_2 atoms interact with O_2 and produce higher NO_x emissions. When compared to diesel fuel, the biodiesel fuels utilized in this experiment have a greater density, a higher aromatic content, and a higher O_2 content More N_2 atoms interact with O_2 because it is present in greater amounts, increasing the amount of NO_x

emissions. In this experimental study, biodiesel fuels are used instead of diesel fuel because they are denser, more aromatic, and contain more O_2 [71].

5.7. Smoke Emissions

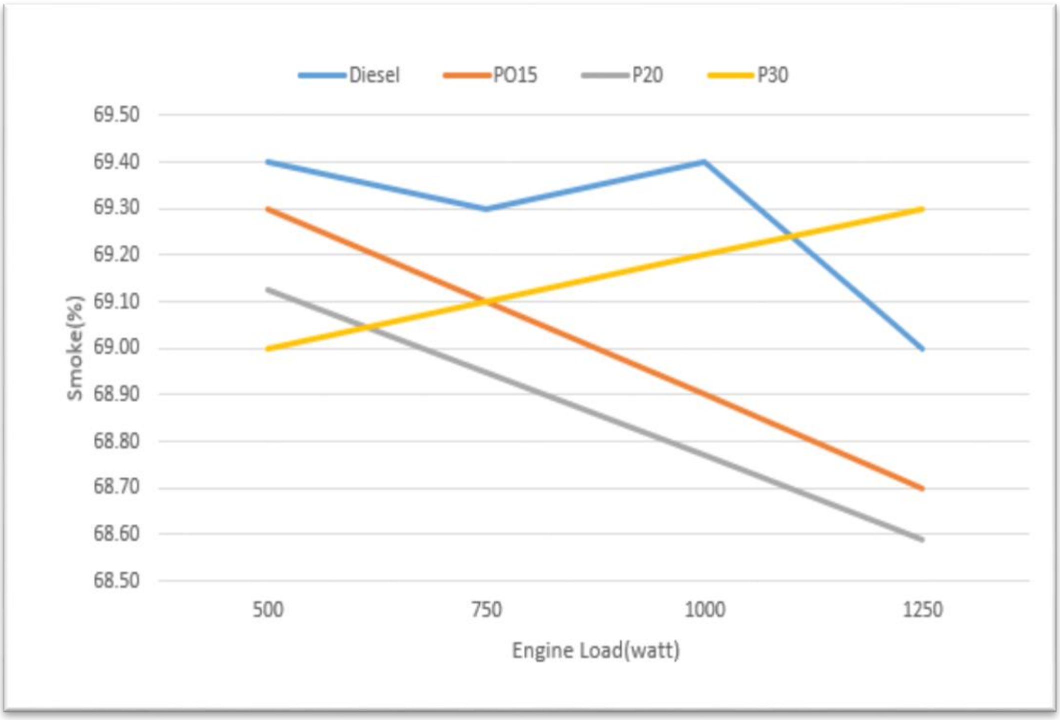

Figure 5.22. Smoke Emissions with Respect to Load an Engine.

Analyzing smoke emissions profiles for different fuels based on engine load is shown in Fig. 5.22. Smoke pollution make up nearly all the solid particles generated by combustion engines. Diesel engines emit more smoke or unburned carbon particles than gasoline engines do. Smoke emissions make up most of the solid particles generated by internal combustion engines. Unburned carbon particles are smoke emissions, which are more common in diesel engines. The residual carbon cannot be burnt off in diesel engines due to a lack of O_2, thus it is discharged as smoke particles. The creation of the smoke emissions is significantly influenced by the amount of O_2 in the cylinder. The extra carbon cannot be burnt off because it cannot find enough O_2 in diesel engines, therefore it is discharged as smoke particles. In these engines, the H_2 molecules in the liquid drop of fuel react swiftly with the O_2 in the cylinder. The liquid's H_2 molecules fuel drop react quickly with the O_2 in the cylinder in these engines. As demonstrated in Table 1, the palm oil biodiesel employed in this experimental investigation contains O_2. As a result, when comparing palm oil biodiesel to diesel, the amount of O_2 that a carbon atom need is greater. In this method, fuels containing palm oil biodiesel had lower smoke emissions than diesel. As the engine load increases and more fuel is delivered, very little O_2 is present, and smoke emissions are increasing. Because using biodiesel enhances the amount of O_2 and smoke emissions are lower at all loads, biodiesel fuels are superior to diesel [71].

5.8. EGT Emissions

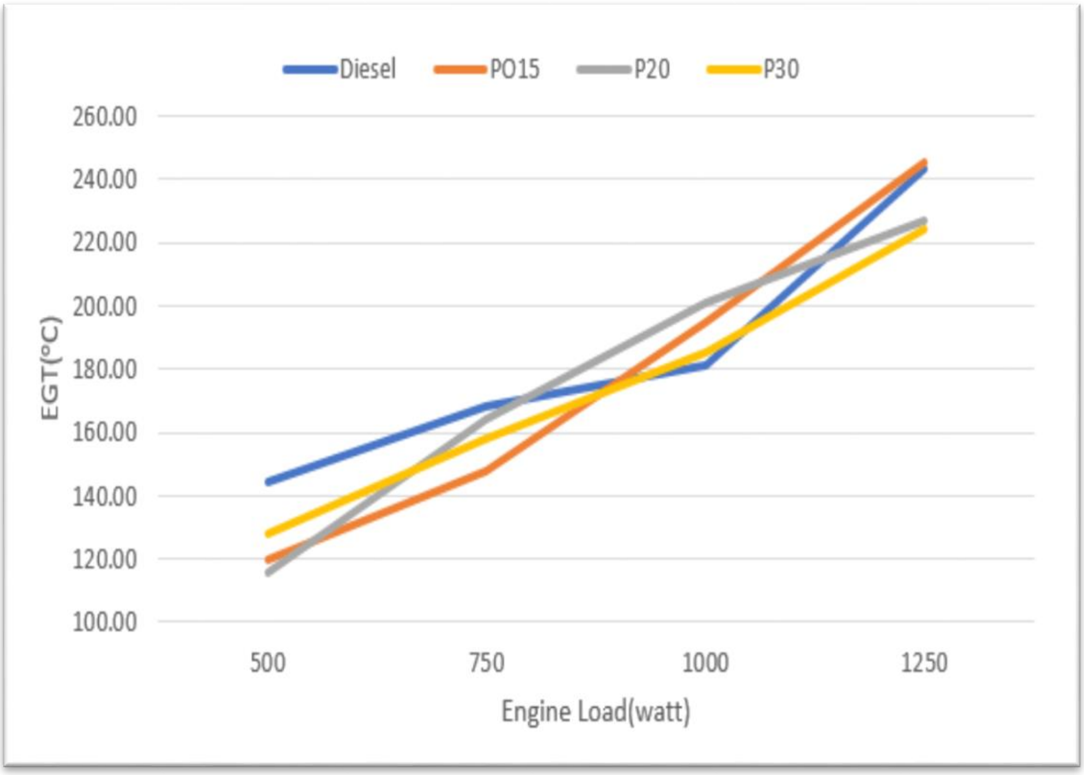

Figure 5.23. EGT with Respect to Engine Load.

Engine load was shown to have an impact on EGT for diesel and biodiesel blends PO15, P20, and P30 in Fig. 5.23. This graph demonstrates how all fuels rise similarly from low load to high load. The temperature of the exhaust gases increases with increasing engine load for all fuels. Due to biodiesel's and oil blends reduced thermal efficiency in comparison to diesel fuel, Exhaust gas heat loss increased. As would be predicted, EGT grew as engine load increased, reaching its peak at 1250 watts of engine output. Naturally, lowering in-cylinder temperatures will also naturally lower exhaust gas temperatures. Because there is O_2 in biodiesel, it is believed to have a cooling impact. EGT increased up to a 50% biodiesel ratio, however after that point, EGT decreased once again up to a 100% biodiesel ratio due to the cooling impact of biodiesel. Better combustion is made possible by biodiesel's O_2 concentration. The engine cylinder temperature may have increased as more gasoline is burnt to meet the higher load demand. As engine duty increased, the rate of heat loss from exhaust gases also increased. Due to the poor combustion properties, biodiesel and oil blends produce higher EGT than fossil diesel for the full engine load Diesel, PO15, P20, and P30 EGT at full load are 243, 195, 226.88, and 224°C, respectively [71].

PART 6

CONCLUSION

In connection to the use of palm oil biodiesel, the efficiency and emission, of an air-cooled, single-cylinder, a single-stroke diesel engine evaluated, either purest form or when combined with diesel fuel. According to the experiment's findings:

- Due to the substantial viscosity, BTE values increased having the use of palm oil biodiesel. As a result of the viscosity value of palm oil biodiesel is reasonably near diesel, the BTE value was produced by diesel. Although the best BTE value was acquired through P20 fuel, The worst resulted from P30.

- Emissions of CO and HC, which are byproducts insufficient combustion, lowered because of better combustion brought about using palm oil-based biodiesel fuels with greater cetane ratings compared to diesel. P30 produced lowest amounts of CO and HC emissions.

- The use of palm oil biodiesel has increased releases of CO_2, which happen in opposition to the status of CO emissions, since CO emissions have decreased. By reducing the rate of incomplete combustion and increasing the rate of complete combustion because of their high cetane values, they also raised the rate of CO_2 emissions, which are a byproduct of full combustion.

- Because of the high O_2 concentration, aromatic content, and density of Palm Oil Biodiesel fuels compared to diesel. While P30 fuel produced the greatest NO_x emission values, diesel-based blends produced lower NO_x levels.

REFERENCES

1. Journal, I. Related Papers. *Over Rim* **2017**, 191–199, doi:10.2307/j.ctt46nrzt.12.

2. Öner, C.; Altun, Ş. Biodiesel Production from Inedible Animal Tallow and an Experimental Investigation of Its Use as Alternative Fuel in a Direct Injection Diesel Engine. *Appl. Energy* **2009**, *86*, 2114–2120, doi:10.1016/j.apenergy.2009.01.005.

3. Karmakar, A.; Karmakar, S.; Mukherjee, S. Properties of Various Plants and Animals Feedstocks for Biodiesel Production. *Bioresour. Technol.* **2010**, *101*, 7201–7210, doi:10.1016/j.biortech.2010.04.079.

4. Hoekman, S.K.; Broch, A.; Robbins, C.; Ceniceros, E.; Natarajan, M. Review of Biodiesel Composition, Properties, and Specifications. *Renew. Sustain. Energy Rev.* **2012**, *16*, 143–169, doi:10.1016/j.rser.2011.07.143.

5. Buyukkaya, E.; Benli, S.; Karaaslan, S.; Guru, M. Effects of Trout-Oil Methyl Ester on a Diesel Engine Performance and Emission Characteristics. *Energy Convers. Manag.* **2013**, *69*, 41–48, doi:10.1016/j.enconman.2013.01.017.

6. El-Araby, R.; Amin, A.; El Morsi, A.K.; El-Ibiari, N.N.; El-Diwani, G.I. Study on the Characteristics of Palm Oil–Biodiesel–Diesel Fuel Blend. *Egypt. J. Pet.* **2018**, *27*, 187–194, doi:10.1016/j.ejpe.2017.03.002.

7. Atadashi, I.M.; Aroua, M.K.; Aziz, A.A. High Quality Biodiesel and Its Diesel Engine Application: A Review. *Renew. Sustain. Energy Rev.* **2010**, *14*, 1999–2008, doi:10.1016/j.rser.2010.03.020.

8. Lloyd, A.C.; Cackette, T.A. Diesel Engines: Environmental Impact and Control. *J. Air Waste Manag. Assoc.* **2001**, *51*, 809–847, doi:10.1080/10473289.2001.10464315.

9. Reitz, R.D. Directions in Internal Combustion Engine Research. *Combust. Flame* **2013**, *160*, 1–8, doi:10.1016/j.combustflame.2012.11.002.

10. Baldwin, D.; Barr, V.; Briggs, A.; Havill, J.; Maxwell, B.; Walker, H.M. CS 1: Beyond Programming (Special Session). *Proc. Conf. Integr. Technol. into Comput. Sci. Educ. ITiCSE* **2017**, *61*, 677–678, doi:10.1145/3017680.3017802.

11. Gigür, A.Iş.; Karaosmanoglu, F.; Aksoy, H.A. Methyl Ester from Safflower Seed Oil of Turkish Origin as a Biofuel for Diesel Engines. *Appl. Biochem. Biotechnol.* **1994**, *45–46*, 103–112, doi:10.1007/BF02941791.

12. Ahn, E.; Koncar, M.; Mittelbach, M.; Man, R. A Low-Waste Process for the Production of Biodiesel. *Sep. Sci. Technol.* **1995**, *30*, 2021–2033, doi:10.1080/01496399508010391.

13. Alfuso, S.; Auriemma, M.; Police, G.; Prati, M.V. The Effect of Methyl-Ester of Rapeseed Oil on Combustion and Emissions of Di Diesel Engines. *SAE Tech. Pap.* **1993**, *102*, 2332–2340, doi:10.4271/932801.

14. Peterson, C.; Reece, D. IN A CHASSIS DYNAMOMETER TEST OF A PICKUP TRUCK. **1996**, *39*, 805–816.

15. Choi, C.Y.; Bower, G.R.; Reitz, R.D. Effects of Biodiesel Blended Fuels and Multiple Injections on D. I. Diesel Engines. *SAE Tech. Pap.* **1997**, *106*, 388–407, doi:10.4271/970218.

16. Moreno, F. S m e f a d E. **1999**, *42*, 1181–1185.

17. Clark, N.N.; Lyons, D.W. C 8 t e T : E t c d b O. **1999**, *42*, 1211–1219.

18. Xue, J.; Grift, T.E.; Hansen, A.C. Effect of Biodiesel on Engine Performances and Emissions. *Renew. Sustain. Energy Rev.* **2011**, *15*, 1098–1116, doi:10.1016/j.rser.2010.11.016.

19. Kurnia, J.C.; Jangam, S. V.; Akhtar, S.; Sasmito, A.P.; Mujumdar, A.S. Advances in Biofuel Production from Oil Palm and Palm Oil Processing Wastes: A Review. *Biofuel Res. J.* **2016**, *3*, 332–346, doi:10.18331/BRJ2016.3.1.3.

20. Kalam, M.A.; Masjuki, H.H. Biodiesel from Palmoil - An Analysis of Its Properties and Potential. *Biomass and Bioenergy* **2002**, *23*, 471–479, doi:10.1016/S0961-9534(02)00085-5.

21. Knie, A. *Diesel - Karriere Einer Technik: Genese Und Formierungsprozesse Im Motorenbau*; 1991; ISBN 3-89404-103-X.

22. Xiao, J.; Li, Q.; Huang, Z. Motion Characteristic of a Free Piston Linear Engine. *Appl. Energy* **2010**, *87*, 1288–1294, doi:10.1016/j.apenergy.2009.07.005.

23. Farmer, H.O. Free-Piston Compressor-Engines. *Proc. Inst. Mech. Eng.* **1947**, *156*, 253–271, doi:10.1243/pime_proc_1947_156_043_02.

24. Fricke, T.; Weisser, W.; Weigelt, A.; Wachendorf, M. Einfluss Der Biodiversität Auf Heizwert Und Energieertrag Extensiver Wiesenbestände Material Und Methoden Ergebnisse Und Diskussion. **2006**, 98–100.

25. Of, S.; Free, T.H.E.; Type, P. 2z ? % 22%. **1941**.

26. *No Tit.צכןle*; ISBN 9783540890829.

27. Hubbert, M.K. Nuclear Energy and the Fossil Fuels. *Drill. Prod. Pract. 1956* 1956, *1956-Janua*, 7–25.

28. Hirsch, R.L.; Bezdek, R.; Wendling, R. Peaking of World Oil Production: Impacts, Mitigation, & Risk Management - Report for the US Department of Energy. *Rep. US Dep. Energy* **2005**, 1–91.

29. Goldemberg, J.; Lucon, O. Energias Renováveis: Um Futuro Sustentável. *Rev. USP* **2007**, *0*, 6, doi:10.11606/issn.2316-9036.v0i72p6-15.

30. Rico, J.A.P.; Sauer, I.L. A Review of Brazilian Biodiesel Experiences. *Renew. Sustain. Energy Rev.* **2015**, *45*, 513–529, doi:10.1016/j.rser.2015.01.028.

31. Geraldes Castanheira, É.; Grisoli, R.; Freire, F.; Pecora, V.; Coelho, S.T. Environmental Sustainability of Biodiesel in Brazil. *Energy Policy* **2014**, *65*, 680–691, doi:10.1016/j.enpol.2013.09.062.

32. Pousa, G.P.A.G.; Santos, A.L.F.; Suarez, P.A.Z. History and Policy of Biodiesel in Brazil. *Energy Policy* **2007**, *35*, 5393–5398, doi:10.1016/j.enpol.2007.05.010.

33. Mekhilef, S.; Siga, S.; Saidur, R. A Review on Palm Oil Biodiesel as a Source of Renewable Fuel. *Renew. Sustain. Energy Rev.* **2011**, *15*, 1937–1949, doi:10.1016/j.rser.2010.12.012.

34. Balasubramanian, D.; Hoang, A.T.; Papla Venugopal, I.; Shanmugam, A.; Gao, J.; Wongwuttanasatian, T. Numerical and Experimental Evaluation on the Pooled Effect of Waste Cooking Oil Biodiesel/Diesel Blends and Exhaust Gas Recirculation in a Twin-Cylinder Diesel Engine. *Fuel* **2021**, *287*, 119815, doi:10.1016/j.fuel.2020.119815.

35. Mantari, M.H.A.R.; Jaafar, M.N.M. Performance of Oil Burner System Utilizingvarious Palm Biodiesel Blends. *Int. J. Mech. Mater. Eng.* **2009**, *4*, 273–278.

36. Taib, N.M.; Abu Mansor, M.R.; Mahmood, W.M.F.W.; Abdullah, N.R. Simulation Study of Combustion Characteristics of Diesel-Ethanol-Palm Oil Methyl Ester Blends in Diesel Engine. *J. Adv. Res. Fluid Mech. Therm. Sci.* **2018**, *44*, 149–156.

37. Selemani, A. Thermal Chemical Enhancement and Influence of Fluid Flow in Transesterification of Palm Oil. *Energy Sources, Part A Recover. Util. Environ. Eff.* **2018**, *40*, 81–87, doi:10.1080/15567036.2017.1405113.

38. Ozsezen, A.N.; Canakci, M. The Emission Analysis of an IDI Diesel Engine Fueled with Methyl Ester of Waste Frying Palm Oil and Its Blends. *Biomass and Bioenergy* **2010**, *34*, 1870–1878, doi:10.1016/j.biombioe.2010.07.024.

39. Devarajan, Y.; Munuswamy, D.B.; Mahalingam, A.; Nagappan, B. Performance, Combustion, and Emission Analysis of Neat Palm Oil Biodiesel and Higher Alcohol Blends in a Diesel Engine. *Energy and Fuels* **2017**, *31*, 13796–13801, doi:10.1021/acs.energyfuels.7b02939.

40. Khan, O.; Khan, M.Z.; Ahmad, N.; Qamer, A.; Alam, M.T.; Khan, M.E.; Siddiqui, A.H. Performance and Emission Analysis on Palm Oil Derived Biodiesel Coupled with Aluminum Oxide Nanoparticles. *Mater. Today Proc.* **2020**, *46*, 6781–6786, doi:10.1016/j.matpr.2021.04.338.

41. Hussain, A.; Mehdi, S.M.; Akhtar, M.; Ani, F.N.; Ahmed, I. Combustion Performance of Diesel Palm Olein Fuel: A Combined CFD and Experimental Approach. *Arab. J. Sci. Eng.* **2018**, *43*, 1291–1300, doi:10.1007/s13369-017-2823-5.

42. Reşitoılu, I.A.; Altinişik, K.; Keskin, A. The Pollutant Emissions from Diesel-Engine Vehicles and Exhaust Aftertreatment Systems. *Clean Technol. Environ. Policy* **2015**, *17*, 15–27, doi:10.1007/s10098-014-0793-9.

43. Prasad, R.; Bella, V.R. A Review on Diesel Soot Emission, Its Effect and Control. *Bull. Chem. React. Eng. & Catal.* **2010**, *5*, 69–86, doi:10.9767/bcrec.5.2.794.69-86.

44. *And*; 2019; ISBN 9780768049749.

45. Wu, C.W.; Chen, R.H.; Pu, J.Y.; Lin, T.H. The Influence of Air-Fuel Ratio on Engine Performance and Pollutant Emission of an SI Engine Using Ethanol-Gasoline-Blended Fuels. *Atmos. Environ.* **2004**, *38*, 7093–7100, doi:10.1016/j.atmosenv.2004.01.058.

46. Raub, J.A. Health Effects of Exposure to Ambient Carbon Monoxide. *Chemosph. - Glob. Chang. Sci.* **1999**, *1*, 331–351, doi:10.1016/S1465-9972(99)00005-7.

47. Kampa, M.; Castanas, E. Human Health Effects of Air Pollution. *Environ. Pollut.* **2008**, *151*, 362–367, doi:10.1016/j.envpol.2007.06.012.

48. Walsh, M.P. Mobile Source Related Air Pollution: Effects on Health and the Environment. *Encycl. Environ. Heal.* **2019**, 436–442, doi:10.1016/B978-0-12-409548-9.11661-6.

49. Strauss, S.; Wasil, J.R.; Earnest, G.S. Carbon Monoxide Emissions from Marine Outboard Engines. *SAE Tech. Pap.* **2004**, *2004-Septe*, doi:10.4271/2004-32-0011.

50. Machado Corrêa, S.; Arbilla, G. Carbonyl Emissions in Diesel and Biodiesel Exhaust. *Atmos. Environ.* **2008**, *42*, 769–775, doi:10.1016/j.atmosenv.2007.09.073.

51. Yamada, H.; Misawa, K.; Suzuki, D.; Tanaka, K.; Matsumoto, J.; Fujii, M.; Tanaka, K. Detailed Analysis of Diesel Vehicle Exhaust Emissions: Nitrogen Oxides, Hydrocarbons and Particulate Size Distributions. *Proc. Combust. Inst.* **2011**, *33*, 2895–2902, doi:10.1016/j.proci.2010.07.001.

52. Zheng, M.; Mulenga, M.C.; Reader, G.T.; Wang, M.; Ting, D.S.K.; Tjong, J. Biodiesel Engine Performance and Emissions in Low Temperature Combustion. *Fuel* **2008**, *87*, 714–722, doi:10.1016/j.fuel.2007.05.039.

53. Payri, F.; Bermúdez, V.R.; Tormos, B.; Linares, W.G. Hydrocarbon Emissions Speciation in Diesel and Biodiesel Exhausts. *Atmos. Environ.* **2009**, *43*, 1273–1279, doi:10.1016/j.atmosenv.2008.11.029.

54. Dhariwal, H.C. Control of Blowby Emissions and Lubricating Oil Consumption in I.C. Engines. *Energy Convers. Manag.* **1997**, *38*, 1267–1274, doi:10.1016/s0196-8904(96)00156-2.

55. D, D.-S. The Role of Diesel Exhaust Dartlicles And. **1997**, *52*, 52–56.

56. Matti Maricq, M. Chemical Characterization of Particulate Emissions from Diesel Engines: A Review. *J. Aerosol Sci.* **2007**, *38*, 1079–1118, doi:10.1016/j.jaerosci.2007.08.001.

57. Kittelson, D.B. Engines and Nanoparticles: A Review. *J. Aerosol Sci.* **1998**, *29*, 575–588, doi:10.1016/S0021-8502(97)10037-4.

58. Agarwal, A.K. Biofuels (Alcohols and Biodiesel) Applications as Fuels for Internal Combustion Engines. *Prog. Energy Combust. Sci.* **2007**, *33*, 233–271, doi:10.1016/j.pecs.2006.08.003.

59. Sarvi, A.; Lyyränen, J.; Jokiniemi, J.; Zevenhoven, R. Particulate Emissions from Large-Scale Medium-Speed Diesel Engines: 1. Particle Size Distribution. *Fuel Process. Technol.* **2011**, *92*, 1855–1861, doi:10.1016/j.fuproc.2011.04.031.

60. Tighe, C.J.; Twigg, M. V.; Hayhurst, A.N.; Dennis, J.S. The Kinetics of Oxidation of Diesel Soots by NO2. *Combust. Flame* **2012**, *159*, 77–90, doi:10.1016/j.combustflame.2011.06.009.

61. Metts, T.A.; Batterman, S.A.; Fernandes, G.I.; Kalliokoski, P. Ozone Removal by Diesel Particulate Matter. *Atmos. Environ.* **2005**, *39*, 3343–3354, doi:10.1016/j.atmosenv.2005.01.027.

62. Stanmore, B.R.; Brilhac, J.F.; Gilot, P. The Oxidation of Soot: A Review of Experiments, Mechanisms and Models. *Carbon N. Y.* **2001**, *39*, 2247–2268, doi:10.1016/S0008-6223(01)00109-9.

63. Sharma, M.; Agarwal, A.K.; Bharathi, K.V.L. Characterization of Exhaust Particulates from Diesel Engine. *Atmos. Environ.* **2005**, *39*, 3023–3028, doi:10.1016/j.atmosenv.2004.12.047.

64. Lee, T.; Park, J.; Kwon, S.; Lee, J.; Kim, J. Variability in Operation-Based NOx Emission Factors with Different Test Routes, and Its Effects on the Real-Driving Emissions of Light Diesel Vehicles. *Sci. Total Environ.* **2013**, *461–462*, 377–385, doi:10.1016/j.scitotenv.2013.05.015.

65. Chong, J.J.; Tsolakis, A.; Gill, S.S.; Theinnoi, K.; Golunski, S.E. Enhancing the NO2/NOx Ratio in Compression Ignition Engines by Hydrogen and Reformate Combustion, for Improved Aftertreatment Performance. *Int. J. Hydrogen Energy* **2010**, *35*, 8723–8732, doi:10.1016/j.ijhydene.2010.06.008.

66. Hoekman, S.K.; Robbins, C. Review of the Effects of Biodiesel on NOx Emissions. *Fuel Process. Technol.* **2012**, *96*, 237–249, doi:10.1016/j.fuproc.2011.12.036.

67. Sharma, H.N.; Suib, S.L.; Mhadeshwar, A.B. Interactions of Sulfur Oxides with Diesel Oxidation Catalysts (DOCs). *ACS Symp. Ser.* **2013**, *1132*, 117–155, doi:10.1021/bk-2013-1132.ch005.

68. Matsumoto, S.; Ikeda, Y.; Suzuki, H.; Ogai, M.; Miyoshi, N. NO(x) Storage-Reduction Catalyst for Automotive Exhaust with Improved Tolerance against Sulfur Poisoning. *Appl. Catal. B Environ.* **2000**, *25*, 115–124, doi:10.1016/S0926-3373(99)00124-1.

69. Engström, P.; Amberntsson, A.; Skoglundh, M.; Fridell, E.; Smedler, G. Sulphur Dioxide Interaction with NO(x) Storage Catalysts. *Appl. Catal. B Environ.* **1999**, *22*, doi:10.1016/S0926-3373(99)00060-0.

70. Lafayette, W. <1-S2.0-002195179190092I-Main.Pdf>. **1991**, *75*, 62–75.

71. Simsek, S.; Uslu, S. Comparative Evaluation of the Influence of Waste Vegetable Oil and Waste Animal Oil-Based Biodiesel on Diesel Engine Performance and Emissions. *Fuel* **2020**, *280*, 118613, doi:10.1016/j.fuel.2020.118613.

72. Dalton, S.; Fariz Mohamed, A.; Ogboo Chikere, A. Status Evaluation of Palm Oil Waste Management Sustainability in Malaysia. *OIDA Int. J. Sustain. Dev.* **2017**, *10*, 12.

73. Lam, M.K.; Tan, K.T.; Lee, K.T.; Mohamed, A.R. Malaysian Palm Oil: Surviving the Food versus Fuel Dispute for a Sustainable Future. *Renew. Sustain. Energy Rev.* **2009**, *13*, 1456–1464, doi:10.1016/j.rser.2008.09.009.

74. Jayed, M.H.; Masjuki, H.H.; Saidur, R.; Kalam, M.A.; Jahirul, M.I. Environmental Aspects and Challenges of Oilseed Produced Biodiesel in Southeast Asia. *Renew. Sustain. Energy Rev.* **2009**, *13*, 2452–2462, doi:10.1016/j.rser.2009.06.023.

75. Eevera, T.; Rajendran, K.; Saradha, S. Biodiesel Production Process Optimization and Characterization to Assess the Suitability of the Product for Varied Environmental Conditions. *Renew. Energy* **2009**, *34*, 762–765, doi:10.1016/j.renene.2008.04.006.

76. Alkabbashi, A.N.; Alam, M.Z.; Mirghani, M.E.S.; Al-Fusaiel, A.M.A. Biodiesel Production from Crude Palm Oil by Transesterification Process. *J. Appl. Sci.* **2009**, *9*, 3166–3170, doi:10.3923/jas.2009.3166.3170.

77. Kabashi, S.; Ahmed, E. University of Science and Technology Faculty of Medicine DEPARTMENT OF COMMUNITY MEDICINE Knowledge of Petrol Station Workers about the Health Effects from Their Occupation in Karari Locality in Omdurman , January 2021. **2021**.

78. Gad, M.S.; El-Araby, R.; Abed, K.A.; El-Ibiari, N.N.; El Morsi, A.K.; El-Diwani, G.I. Performance and Emissions Characteristics of C.I. Engine Fueled with Palm Oil/Palm Oil Methyl Ester Blended with Diesel Fuel. *Egypt. J. Pet.* **2018**, *27*, 215–219, doi:10.1016/j.ejpe.2017.05.009.

79. El-Baz, F.K.; Gad, M.S.; Abdo, S.M.; Abed, K.A.; Matter, I.A. Performance and Exhaust Emissions of a Diesel Engine Burning Algal Biodiesel Blends. *Int. J. Mech. Mechatronics Eng.* **2016**, *16*, 151–158.

80. Ibrahim, S.M.A.; Abed, K.A.; Gad, M.S. Experimental Investigation of Diesel Engine Performance Burning Preheated Jatropha Oil. *World Appl. Sci. J.* **2014**, *31*, 1231–1236, doi:10.5829/idosi.wasj.2014.31.07.14360.

81. Simsek, S.; Uslu, S. Comparative Evaluation of the Influence of Waste Vegetable Oil and Waste Animal Oil-Based Biodiesel on Diesel Engine Performance and Emissions. *Fuel* **2020**, *280*, 118613, doi:10.1016/j.fuel.2020.118613.

82. McCormick, M.S.G. and R.L.; Colorado COMBUSTION OF FAT A N D VEGETABLE OIL DERIVED FUELS IN DIESEL ENGINES Michael S. Graboski* and Robert L. McCormick. *Science (80-.).* **1998**, *24*, 125–164.

83. Encinar, J.M.; González, J.F.; Rodríguez-Reinares, A. Biodiesel from Used Frying Oil. Variables Affecting the Yields and Characteristics of the Biodiesel. *Ind. Eng. Chem. Res.* **2005**, *44*, 5491–5499, doi:10.1021/ie040214f.

84. Canakci, M.; Gerpen, J.H. Van C e p e p d f y g b s o B. **2003**, *46*, 937–944.

85. Ma, F.; Hanna, M.A. Biodiesel Production: A Review1Journal Series #12109, Agricultural Research Division, Institute of Agriculture and Natural Resources, University of Nebraska–Lincoln.1. *Bioresour. Technol.* **1999**, *70*, 1–15, doi:10.1016/s0960-8524(99)00025-5.

86. Teraishi, T.; Miura, K. Detection of Phosphorylated Mitogen-Activated Protein Kinase in the Developing Spinal Cord of the Mouse Embryo. *Biochem. Biophys. Res. Commun.* **2011**, *413*, 87–91, doi:10.1016/j.bbrc.2011.08.056.

87. Kusdiana, D.; Saka, S. Effects of Water on Biodiesel Fuel Production by Supercritical Methanol Treatment. *Bioresour. Technol.* **2004**, *91*, 289–295, doi:10.1016/S0960-8524(03)00201-3.

88. Pattanaik, B.P.; Jena, J.; Misra, R.D. The Effect of Oxygen Content in Soapnut Biodiesel-Diesel Blends on Performance of a Diesel Engine. *Int. J. Automot. Mech. Eng.* **2017**, *14*, 4574–4588, doi:10.15282/ijame.14.3.2017.14.0361.

89. Senatore, A.; Cardone, M.; Rocco, V.; Prati, M. V. A Comparative Analysis of Combustion Process in D.I. Diesel Engine Fueled with Biodiesel and Diesel Fuel. *SAE Tech. Pap.* **2000**, doi:10.4271/2000-01-0691.

90. Shehata, M.S. Emissions, Performance and Cylinder Pressure of Diesel Engine Fuelled by Biodiesel Fuel. *Fuel* **2013**, *112*, 513–522, doi:10.1016/j.fuel.2013.02.056.

RESUME

Mahdi Hussein Nasser attended school in Lebanon. He finished his high school education at Modern Lebanese Family School, afterward, he began his undergraduate bachelor's program at Matn University College (MUC). Department of Technology in 2016. Then in 2020, he started his master's program at Karabuk University, Department of Mechanical Engineering.