

EMISSION EXAMINATION ON A NANO PARTICLES, BIO-DIESEL BLENDED WITH CONSTANT SPEED DIESEL ENGINE

Submitted in partial fulfillment of the requirements for the award of
Bachelor of engineering degree in
Mechanical Engineering

By

S.GOPINATH (REG. NO. 38150033)

M.HARIKRISHNAN (REG. NO. 38150034)



DEPARTMENT OF MECHANICAL ENGINEERING

SCHOOL OF MECHANICAL ENGINEERING

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with Grade "A" by NAAC

JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600119

MAY 2022



SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)

Accredited with Grade "A" by NAAC

JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600119

www.sathyabama.ac.in



DEPARTMENT OF MECHANICAL ENGINEERING

BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **S.GOPINATH (Reg.No. 38150033)** and **M.HARIKRISHNAN (Reg.No. 38150034)** who have done the Project work "EMISSION EXAMINATION ON A NANO PARTICLES, BIO-DIESEL BLENDED WITH CONSTANT SPEED DIESEL ENGINE " as a team under our supervision from December 2021 to April 2022.

Internal Guide

Mr.J. SENTHILKUMAR, M.E., (PhD)

Head of the Department

Dr.G. ARUN KUMAR, M.E., Ph.D.

Submitted for Viva voce Examination held on _____

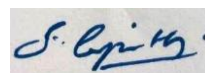
Internal Examiner

External Examiner

DECLARATION

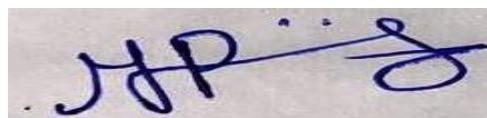
We **S.GOPINATH (Reg.No. 38150033)** and **M.HARIKRISHNAN (Reg.No. 38150034)** hereby declare that the Project Report entitled “**EMISSION EXAMINATION ON A NANO PARTICLES, BIO-DIESEL BLENDED WITH CONSTANT SPEED DIESEL ENGINE**” done by me under the guidance of **Mr.J.Senthilkumar, M.E., (PhD).**, is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Mechanical Engineering.

DATE:



PLACE:

SIGNATURE OF THE CANDIDATE
S. GOPINATH
38150033



SIGNATURE OF THE CANDIDATE
M.HARIKRISHNAN
38150034

ACKNOWLEDGEMENT

I am pleased to acknowledge my sincere thanks to Board of Management of **SATHYABAMA** for their kind encouragement in doing this project and for completing it successfully. I am grateful to them.

I convey my thanks to **Dr. S. Prakash, M.E., Ph.D., Dean, School of Mechanical Engineering** and **Dr. G. Arun Kumar, M.E., Ph.D., Head of the Department, Mechanical Engineering** for providing me necessary support and details at the right time during the progressive reviews.

I would like to express my sincere and deep sense of gratitude to my Project Guide **Mr.J.Senthilkumar, M.E., (PhD)., Assistant Professor, Department of Mechatronics Engineering** for his valuable guidance, suggestions and constant encouragement paved way for the successful completion of our project work.

I wish to express my thanks to all Teaching and Non-teaching staff members of the Department of Mechanical and Production Engineering who were helpful in many ways for the completion of the project.

ABSTRACT

Energy demand is the hot topic of all developing and developed countries. Every day Energy demand increases in a big rate. So, it is necessary to find an eco-friendly alternative solution, biodiesel is a promising alternative solution for this problem. The main purpose of this paper is to test and compare the performance, Emission and Combustion behavior of diesel engine using Pithecellobium dulce Seed Oil biodiesel blended separately and mixed nano particles for Cerium oxide and nickel oxide is used as a catalyst. Pithecellobium dulce Seed Oil were esterified using the transesterification method. Then samples S1, S2 and S3 were prepared using sonication process for each nano materials . The measuring parameters are break power, break thermal efficiency, specific fuel consumption, emission parameter like NO_x, HC, CO, and CO₂ were measured during the experimentation.

TABLE OF CONTENT

Chapter No	TITLE	Page No
	ABSTRACT	V
	LIST OF FIGURES	IX
	LIST OF TABLES	X
1	INTRODUCTION	1
	1.1 OUTLINE OF THE PROJECT	2
	1.2 EMISSION FROM DIESEL ENGINE	5
	1.3 MAIN LOCAL AIR POLLUTENTS	5
	1.3.1 Carbon Monoxide	5
	1.3.2 Nitrogen Oxides	5
	1.3.3 Particulates	6
	1.3.4 Sulphur Dioxide	6
	1.3.5 Butadiene	6
	1.3.6 Volatile Organic Compounds	6
	1.4 COMPRESSION ENGINE IGNITION	6
	1.5 PROBLEM STATEMENT AND RESEARCH OBJECTIVES	7
	1.6 NECESSITY OF ALTERNATIVE FUELS	8
	1.7 BIOFUEL	8
	1.8 BIODIESEL	9
	1.8.1 Biodiesel Production	10
	1.8.2 Biodiesel Feature	10
	1.8.3 Advantages of Biodiesel	11
	1.8.4 Process Description	12
	1.9 ESSENTIAL OIL	13
	1.10 ESSENTIAL OIL CATEGORIES	13
	1.10.1 Camphoraceous	13
	1.10.2 Floral	13
	1.10.3 Mint	13

	1.10.4 Musky	14
	1.10.5 Spicy	14
	1.10.6 Sweet	14
	1.11 COMMONLY USED TYPES	14
	1.11.1 Clary sage	14
	1.11.2 Eucalyptus	14
	1.11.3 Lavender	14
	1.11.4 Lemon oil	14
	1.11.5 Peppermint	14
	1.11.6 Sweet orange oil	14
	1.11.7 Rosemary	14
	1.11.8 Tea tree	14
	1.11.9 Cinnamon oil	15
	1.12 TRANESTERIFICATION	15
	1.13 PITHECELLOBIUM DULCE SEED OIL	16
	1.13.1 Country where its found	16
	1.13.2 History of the plant	16
	1.13.3 Extraction Process	17
	1.13.3.1 Steam distillation process	17
	1.13.3.2 Hydro distillation process	18
2	LITERATURE REVIEW	19
3	AIM AND SCOPE OF THE PROJECT	23
	3.1 AIM	23
	3.2 SCOPE	23

4	METHODOLOGY AND EXPERIMENTAL WORK	24
	4.1 METHODOLOGY	24
	4.2. PITHECELLOBIUM DULCE SEED BIOFUEL	25
	4.2.1 Transesterification process	25
	4.2.2 Nanoparticle additives	26
	4.3 EXPERIMENTAL SETUP	27
	4.3.1 Engine details	27
	4.3.2 Combustion Parameters	27
	4.3.3 specification of gas analyzer	29
	4.3.4. Measuring ranges	29
	4.3.5. Precision	29
	4.3.6. Resolution	29
	4.3.7 procedure of experiment	30
	4.4. AVL GAS ANALYSER	31
	4.5 SONICATION PROCESS	32
	4.6 EXPERIMENTAL TEST	33
5	RESULT AND DISCUSSION	34
	5.1 BRAKE THERMAL EFFICIENCY	35
	5.2 BRAKE SPECIFIC FUEL CONSUMPTION	36
	5.3 CARBON MONOXIDE EMISSION (CO)	36
	5.4 HYDROCARBON EMISSION (HC)	37
	5.5 NITRIC OXIDE EMISSION (NO _x)	38
	5.6 CARBON DIOXIDE (CO ₂)	39
6	CONCLUSION	41
	REFERENCES	

LIST OF FIGURES		
Figure	TITLE	Page
No.		No.
1.1	Pithecellobium dulce Seed oil	17
1.2	Pithecellobium dulce Seed oil Steam distillation apparatus	18
4.1	Methodology	24
4.2	Nanoparticles (Cerium Oxide (CeO_2) and Nickle Oxide (NiO))	26
4.3	Engine set up	27
4.4	Test Samples	30
4.5	Gas Analyser	31
4.6	Sonication Process	32
4.7	Engine Test	33
5.1	Load Vs Brake thermal efficiency	34
5.2	Load Vs Brake specific fuel consumption	35
5.3	Load Vs Carbon monoxide	36
5.4	Load Vs Hydrocarbon	37
5.5	Load Vs Nitric oxide	39
5.6	Load Vs Carbon dioxide	40

LIST OF TABLES		
Table No.	TITLE	Page No.
4.1	Properties of Pithecellobium dulce Seed Oil	25
4.2	Transesterification Report of Pithecellobium dulce Seed biodiesel	26
4.3	Engine Specifications	27
4.4	Performance Parameters	28
5.1	Brake thermal efficiency in %	34
5.2	Specific fuel consumption in Kg/kWh	35
5.3	Emission in CO (ppm)	36
5.4	HC Emission in (ppm)	37
5.5	NOx Emission in ppm	38
5.6	CO ₂ Emission in (%)	39

CHAPTER I

INTRODUCTION

Major research is focused on fuel consumption and emission reduction in the past few years. There is growing interest on alternative fuels due to volatile fossil fuel price and depletion. In many applications like Transportation, Power generation, Marine applications etc., diesel Engines are being used as a major source. During last century, the uses of fossil resources are increasing due to significant growth of population and change in life style. This causes crises of fossil fuel depletion For the diesel engines there is an urgent need for suitable alternative fuels. In this project we will examine the use of diesel-wheat germ oil in diesel four stroke engine. With diesel and different blends of germ oil, an attempt will be made to analyze the performance and emission characteristics of a diesel engine. Internal combustion engines generate undesirable emissions during the combustion process. The pollutants that are exhausted from the internal combustion engines affect the atmosphere and cause problems such as global warming, smog, acid rain, respiratory hazards etc. The physical and chemical conditions that exist inside any such diesel engines under any conditions differ considerably from spark-ignition engines, because, by design, diesel engine power is directly controlled by the fuel supply, not by control of the air/fuel mixture, as in conventional gasoline engines. As a result of these differences, diesel engines generally produce a different array of pollutants than spark-driven engines, differences that are sometimes qualitative (what pollutants are there, and what are not), but more often quantitative (how much of particular pollutants or pollutant classes are present in each). For instance, diesel engines produce one-twenty-eighth the carbon monoxide that gasoline engines do, as they burn their fuel in excess air even at full load.

Particulate matter or soot is created during the incomplete combustion of diesel fuel. Its composition often includes hundreds of chemical elements, including sulfates, ammonium, nitrates, elemental carbon, condensed organic compounds, and even carcinogenic compounds and heavy metals such as arsenic, selenium, cadmium and zinc. Though just a fraction of the width of a human hair, particulate matter varies in size from coarse particulates (less than 10 microns in diameter) to

fine particulates (less than 2.5 microns) to ultrafine particulates (less than 0.1 microns). Ultrafine particulates, which are small enough to penetrate the cells of the lungs, make up 80-95% of diesel soot pollution. Diesel engines contribute to the problem by releasing particulates directly into the air and by emitting nitrogen oxides and sulfur oxides, which transform into "secondary" particulates in the atmosphere. Like all fuel-burning equipment, diesel engines produce nitrogen oxides, which can damage lung tissue, lower the body's resistance to respiratory infection and worsen chronic lung diseases, such as asthma. They also react with other pollutants in the atmosphere to form ozone, a major component of smog.

Acute effects of diesel exhaust exposure include irritation of the nose and eyes, lung function changes, respiratory changes, headache, fatigue and nausea. Chronic exposures are associated with cough, sputum production and lung function decrements. However, a large number of epidemiological studies from different parts of the world have consistently identified an association between ambient levels of air particles and various health outcomes, including mortality, exacerbation of asthma, chronic bronchitis, respiratory tract infections, ischaemic heart disease and stroke. Diesel engines also produce submicron soot particles that are believed to mediate several of the observed adverse effects.

It has been estimated that the particulate emission from diesel engines per travelled distance is over 10 times higher than the emission from petrol engines of equivalent power running on unleaded petrol, and over 100 times higher than that from petrol engines fitted with catalytic converters. Most major sources of diesel emissions, such as ships, trains, and trucks operate in and around ports, rail yards, and heavily travelled roadways. The major components of PM are sulphates, nitrates, ammonia, sodium chloride, black carbon, mineral dust and water. The most health-damaging particles are those with a diameter of 10 μm or less, which can penetrate and lodge deep inside the lungs. Both short- and long- term exposure to air pollutants have been associated with health impacts.

1.1 OUTLINE OF THE PROJECT

Major research is focused on fuel consumption and emission reduction in the past few years. There is growing interest on alternative fuels due to volatile fossil fuel price and depletion. In many applications like Transportation, Power generation,

Marine applications etc., diesel Engines are being used as a major source. During last century, the uses of fossil resources are increasing due to significant growth of population and change in life style. This causes crises of fossil fuel depletion For the diesel engines there is an urgent need for suitable alternative fuels. In this project we will examine the use of diesel-wheat germ oil in diesel four stroke engine. With diesel and different blends of germ oil, an attempt will be made to analyze the performance and emission characteristics of a diesel engine. Internal combustion engines generate undesirable emissions during the combustion process. The pollutants that are exhausted from the internal combustion engines affect the atmosphere and cause problems such as global warming, smog, acid rain, respiratory hazards etc. The physical and chemical conditions that exist inside any such diesel engines under any conditions differ considerably from spark-ignition engines, because, by design, diesel engine power is directly controlled by the fuel supply, not by control of the air/fuel mixture, as in conventional gasoline engines. As a result of these differences, diesel engines generally produce a different array of pollutants than spark-driven engines, differences that are sometimes qualitative (what pollutants are there, and what are not), but more often quantitative (how much of particular pollutants or pollutant classes are present in each). For instance, diesel engines produce one-twenty-eighth the carbon monoxide that gasoline engines do, as they burn their fuel in excess air even at full load.

Particulate matter or soot is created during the incomplete combustion of diesel fuel. Its composition often includes hundreds of chemical elements, including sulfates, ammonium, nitrates, elemental carbon, condensed organic compounds, and even carcinogenic compounds and heavy metals such as arsenic, selenium, cadmium and zinc. Though just a fraction of the width of a human hair, particulate matter varies in size from coarse particulates (less than 10 microns in diameter) to fine particulates (less than 2.5 microns) to ultrafine particulates (less than 0.1 microns). Ultrafine particulates, which are small enough to penetrate the cells of the lungs, make up 80-95% of diesel soot pollution. Diesel engines contribute to the problem by releasing particulates directly into the air and by emitting nitrogen oxides and sulfur oxides, which transform into "secondary" particulates in the atmosphere. Like all fuel-burning

equipment, diesel engines produce nitrogen oxides, which can damage lung tissue, lower the body's resistance to respiratory infection and worsen chronic lung diseases, such as asthma. They also react with other pollutants in the atmosphere to form ozone, a major component of smog.

Several air pollutants contribute to the acidification of the environment. The most important ones are discussed in this article and comprise sulphur dioxide (SO_2), nitrogen oxides (NO_x) and ammonia (NH_3). The impact of SO_2 , NO_x and NH_3 can be observed in the progressive degradation of soils, water and forests. They also contribute to the formation of fine particles in the air that cause respiratory diseases. The acidifying potential of SO_2 , NO_x and NH_3 is commonly measured in SO_2 equivalents.

Acute effects of diesel exhaust exposure include irritation of the nose and eyes, lung function changes, respiratory changes, headache, fatigue and nausea. Chronic exposures are associated with cough, sputum production and lung function decrements. In addition to symptoms, exposure studies in healthy humans have documented a number of profound inflammatory changes in the airways, notably, before changes in pulmonary function can be detected. It is likely that such effects may be even more detrimental in asthmatics and other subjects with compromised pulmonary function. There is growing international concern regarding the adverse health effects of air pollution. Pollution is becoming an important public health problem and political issue, due to the rapid growth in world population and the increasing world-wide migration from rural to urban areas. United Nations estimates have indicated that 47% of the global population is living in urban areas. This urbanization has brought with it an increased need for transportation and hence an increase in motor vehicle generated air pollutants. However, a large number of epidemiological studies from different parts of the world have consistently identified an association between ambient levels of air particles and various health outcomes, including mortality, exacerbation of asthma, chronic bronchitis, respiratory tract infections, ischaemic heart disease and stroke. Diesel engines also produce submicron soot particles that are believed to mediate several of the observed adverse effects.

1.2 EMISSION FROM DIESEL ENGINE

Diesel engines have been used in heavy duty applications for a very long time now; it is only recently that it has become very popular in light duty application due to their higher fuel efficiency. Higher fuel efficiency in the diesel engines is achieved due to the high compression ratios along with high oxygen concentration in the combustion chamber. However, these same factors results 2 in high NO_x emission in diesel engine. The main pollutants of diesel engines are NO_x and particulate matter (PM). The mechanism of formation of Nitrogen oxides and particulate matter inside the combustion chamber of diesel engines are contradictory and the simultaneous reduction of both at the same time is very difficult. Researchers have attempted to reduce the emissions and improve the fuel efficiency of diesel engines.

Diesel engines have been used in heavy duty applications for a long time; it is only during the past decade that it has become very popular in light duty application due to their high fuel efficiency. Higher fuel efficiency in the diesel engine is achieved because of the high compression ratios along with relatively higher oxygen concentration in the combustion chamber. However, these same factors results in higher NO_x emission in diesel engine. The stringent emission norms have been an important driving force to develop the internal combustion engines in a more environment friendly way. The main pollutants from diesel engines are NO_x and particulate matter (PM). The mechanism of formation of NO_x and particulate matter in the combustion chamber of diesel engines are contradictory and the simultaneous reduction of both is very difficult. Researchers have attempted to reduce the emissions and improve the fuel conversion efficiency of diesel engines.

1.3. MAIN LOCAL AIR POLLUTENTS

1.3.1 Carbon Monoxide: CO A gas formed by the incomplete combustion of carbon-containing fuels. The more efficient the combustion processes the lower the emissions. The main outdoor source of CO is currently road transport.

1.3.2. Nitrogen Oxides: NO_x All combustion products in air produce oxides of nitrogen: nitrogen dioxide (NO₂) and nitric oxide (NO) – collectively known as NO_x. Road transport accounts for about 50% of total emissions, more than the electricity supply industry and the industrial and commercial sectors put together. NO_x is also a precursor of ozone and therefore an indirect greenhouse gas.

1.3.3. Particulates: PM₁₀ Particulate matter smaller than 10 microns (10 millionths of a metre). They consist of primary particles arising from combustion sources (mainly road transport); secondary particles (mainly sulphate and nitrate formed by atmospheric chemical reactions); and coarse particles (suspended soils and 3 dusts, sea salt, biological particles and particles from construction work).

Ultra-fine particles (smaller than 2.5 microns) are mainly primary and secondary.

1.3.4. Sulphur Dioxide: SO₂, the predominant source is the combustion of sulphur-containing fossil fuels, principally coal and heavy oils. Output from road vehicles is relatively small, but combustion of fuel (especially diesel) makes a significant contribution to emission levels in urban areas.

1.3.5. 1, 3 Butadiene: A gas at normal temperatures and pressures deriving mainly from the Combustion of diesel and petrol engines.

1.3.6. Volatile Organic Compounds: VOC In sunlight these react with NO_x to form ozone. It can therefore be considered an indirect greenhouse gas. So high concentrations generally occur downwind of the source emissions, most frequently in summer, in the south, and in rural and suburban areas. (Source: HM Customs and Excise, Using the tax system to encourage cleaner fuels, November 2000)

. 1.4 COMPRESSION ENGINE IGNITION

Emissions from a CI engine are a strong function of equivalence ratio (Φ). Common exhaust emissions from a CI engine are oxides of nitrogen (NO_x), carbon monoxides (CO), unburned hydrocarbons (HC) and particulate matters (PM). NO_x formation is dependent on the oxidation of atmospheric nitrogen and is strongly affected by the cylinder charge temperature. Total emission of NO_x in a CI engine is higher compared to lean burn spark-ignition (SI) engines because combustion takes place as a diffusion flame which occurs at Φ close to 1.0. In this region, the stoichiometric air-fuel ratio reaches very high temperatures accounting for the high level of NO_x. CI engines that operate at a very lean mixture with excess air can help to control the NO_x. Combustion gases in lean mixture continue to mix with excess air resulting in lower temperatures that weakens the kinetics of NO_x formation. SI engines that operate close to stoichiometric produces higher NO_x levels than CI engines. Maximum flame temperature which occurs at stoichiometric air-fuel ratio leads to the dissociation engines, because of the non-homogeneity of air-fuel mixture, some local spots in the cylinder will be too lean to burn, leading to misfire and poor combustion. 5 Other spots may be too rich with

not enough oxygen to react with all the carbons. Both conditions of lean and rich mixture produce high HC emission. For CO emission, it is formed when an engine runs rich, therefore its formation does not depend on the intake mixture condition. PM emission in CI engine is formed mostly in the fuel rich zone where Φ is higher than 1.0 within the cylinder during the combustion due to incomplete combustion of fuel hydrocarbons and some from lubricating oil.

1.5. PROBLEM STATEMENT AND RESEARCH OBJECTIVES

Higher fuel costs and increasingly stringent emission regulations are concerns for manufacturers and operators of compression ignition engines. By converting the CI unit to dual fuel operation and utilizing lower cost natural gas, both lower fuel costs and lower emissions can be achieved. However, the cost savings through diesel displacement and emission reductions need to be quantified. Thus, the main purpose of this research is to address the challenges associated with dual fuel engines in order to improve efficiency and to obtain better control of the exhaust emissions. Since dual fuel engines produce higher HC and CO emissions than regulations allow, concepts should be developed to advantageously control combustion and emissions.

1) Does dual fuel operation save cost compared to diesel operation?

Hypothesis: Over the past five years, natural gas fuel prices have remained well below that of diesel fuel and have been more consistent compared to diesel fuel. When natural gas is introduced in diesel engine, it should displace some of the diesel fuel in CI engine, therefore reduce the fuel cost in dual fuel engine.

2) Do dual fuel engines reduce NO_x and PM emission compared to diesel engines?

Hypothesis: Being a lowest member in paraffin family, the diesel combustion with natural gas in dual fuel engine is expected to produce less PM. In addition, since the premixed combustion happens, the opportunity for locally rich mixtures to form is reduced. Therefore, with lean conditions, the flame temperature should be lower, thus reducing the NO_x formation in a dual fuel engine.

3) Do dual fuel engines emit excessive HC and CO?

Hypothesis: The ratio for the natural gas and air entering the cylinder is not controlled. It is speculated that at these load conditions, the natural gas air mixture

is below the flammability limit in the cylinder and the penetration of the diesel fuel jet does not extend across the cylinder. Consequently, regions near the edge of the combustion chamber with natural gas and air mixtures below the flammability limit are either unburned (HC emission) or partially burned (CO emission).

Given the problem statement above, the research objectives are as follows:

- 1) To evaluate the emissions and performance of a dual fuel engine and compare the results with the diesel equivalent.
- 2) To develop an emissions control methodology in order to maintain applicable regulatory standards on emissions levels.
- 3) To investigate in-cylinder combustion by implementing the CFD simulation using CONVERGE code with a reduced chemical-kinetic mechanism for time saving. The location where the emission is formed will be investigated as well.

1.6 NECESSITY OF ALTERNATIVE FUELS

It is clear from the above deliberations that, nowadays India is facing the twin problems of fast exhaustion of fossil fuels and environmental degradation. Hence, there is an urgent need to reduce dependence on petroleum derived fuels for better economy and environment. Adaptation of bio-origin unconventional fuels can address both issues. These fuels are basically nonpetroleum and result in energy security and environmental benefits. They are available either in one form or other for more than one hundred years. The identification of alternative fuels for use in I.C. engines has been subjected to studies throughout the globe. Performance investigations have shown suitability of variety of alternative fuels such as hydrogen, alcohols, biogas, producer gas and various types of edible and non-edible oils. However, in the Indian context, the bio-origin fuels like alcohols, vegetable oils, and biogas can be used extensively and address the problems related to fuel crisis.

1.7 BIO-FUELS

In the transportation and agriculture sectors, various renewable liquid bio-fuels derived from biological resources have proved to be good alternatives to fuels derived from crude oils. For the problems of environmental degradation, energy security, restricting imports, rural employment and agricultural economy, these biofuels are gaining global acceptance as a solution. The most promising biofuels, and closest to being competitive in current markets without subsidy, are ethanol, methanol, vegetable oils and biodiesel.

Ethanol is used as fuel or as oxygenate to gasoline. Biodiesel is a derivative of vegetable oils and is made from virgin or used edible and non-edible vegetable oils and animal fats through a chemical process named transesterification. Biodiesel can be blended in any ratio with petroleum diesel fuel. Its higher Cetane number increases the combustion even when blended in the petroleum. Several studies around the world reveal that if biomass energy is used instead of fossil fuels, there will be a net reduction in CO emissions and CO₂ emissions. SO₂ emissions from using biomass energy tend to be considerably lower because relevant plants and trees contain only trace quantities of sulphur compared to the considerably higher emissions from coal, gasoline, and even some natural gas. This drop in SO₂ is accompanied by a fall in the level of the other traditional motor pollutant emissions such as carbon monoxide, unburned hydrocarbons, and particulates. However, there is an increase in the release of nitrogen oxides and aldehydes.

1.8 BIODIESEL

Biodiesel is a vegetable oil-based (soy or canola oil) fuel that runs in the present diesel engines, without any modifications to the hardware. Biodiesel and biodiesel blends can be used in all compression-ignition (CI) engines that were designed to be operated on diesel fuel. It is cheaper than oil, sustainable, and nontoxic; it does not produce acid rain (absence of sulfur); and it does not contribute as much as fossil fuels do to global warming. Studies have shown it reduces engine wear by as much as 30%, primarily because it provides excellent lubrication (Agarwal, Bijwe, and Das, 2003). Even 2% biodiesel in normal diesel will help achieve this improvement. Biodiesel fuel yields 220% more energy than that required to produce, transport, and distribute it, which is due to the fact that the feedstock crop collects solar energy and transforms it into the biodiesel feedstock oil. Various biodiesel blends, which include different ratios of biodiesel and diesel from crude oil, can be used in vehicles depending upon the vehicle's requirement and weather conditions. A 20% biodiesel will provide a higher octane rating, superior lubricate, significant emission reductions, and less toxic emissions; will virtually eliminate visible soot emissions; and will have similar fuel consumption, horsepower, and torque. Premium biodiesel is a fuel manufactured

from vegetable oils by a transesterification process. Soybean oil is currently the leading source of vegetable oil for biodiesel manufacture in the United States

1.8.1 Biodiesel Production

The commercial method used for the biodiesel production is the transesterification (also called alcoholysis). The transesterification consists on the reaction of oils or fats (triglycerides between 15 and 23 atoms, being the most common with 18) with an alcohol of low molecular weight (usually ethanol or methanol) with the presence of an alkaline catalyst (usually NaOH or KOH) to produce esters and glycerin. Normally, the reaction takes place at atmospheric pressure and 65°C of temperature. The process uses constant agitation, during an interval of time between one or twelve hours. The transesterification consists of three consecutive and reversible reactions (Figure 1). The stoichiometric ratio for the transesterification reaction is three moles of alcohol and one mole of triglyceride (Figure 2). An extra amount of alcohol is added in order to move the reaction to the methyl esters formation. Glycerin is also formed in the reaction.

1 oil/fat + 3 methanol = 3 methyl esters +1 glycerin Figure 2. Transesterification reaction

1.8.2 Biodiesel Features

The biodiesel properties depend on the used feedstock (new vegetable oil, waste cooking oils, animal fats, etc). Important properties of the biodiesel are:

- It can be used pure or blended with petrodiesel in engines
- It can be used in the diesel engine without any modifications.
- it can be storage in the same containers than Petro diesel
- It can prolong engine life due to the higher lubrication capacity
- It improves combustion process. The biodiesel contains at least 11% oxygen. Biodiesel burns better (more completely with few fuel unburned emissions) than petroleum diesel. Less smoke is produced. The use of biodiesel can reduce the emissions of unburned hydrocarbons (HI) in a 90%.
- It generates employment
- It lubricates moving engines
- It is Biodegradable
- It does not contain sulfur. No sulfur emissions are emitted during the combustion
- It is less inflammable compared with Petro diesel.
- During the combustion biodiesel emits less harmful gases into the environment compared with Petro diesel. Biodiesel reduces the

health risks associated with petroleum diesel. The use of biodiesel decreases emission of PAH (identified as cancer causing). Biodiesel is nontoxic.

Greenhouse gas benefit. During the combustion of biodiesel, the CO₂ cycle is closed. The CO₂ produced during the combustion is the amount of CO₂ which the plants are able to metabolize through photosynthesis during growth. Moreover, this process implies low emissions of CO₂, due to the medium content carbon for plants is 77.8% and for animal fats is 76.1%. While, the content carbon for fossil diesel is 86.7%. The use of biodiesel can reduce the CO₂ emissions up to 50% in comparison to the use of petroleum diesel. • The biodiesel transport and its storage are less dangerous than the petroleum diesel, because biodiesel has a flashpoint temperature of about 170°C in comparison of 60 to 80 °C for petroleum diesel. • It is non-irritating to the skin • It has a pleasant aroma

Moreover, those advantages also other economic aspects can be taken into account: a) Biodiesel contribute to diversification of energy sources. It is an important aspect for countries without fossil fuel sources. b) The biodiesel contributes to agricultural and rural development. The most important biodiesel disadvantages, in comparison with the fossil fuel, are: 1) The cost. The biodiesel production is today expensive compared with Petro diesel. 2) The biodiesel needs more additives, mainly in cold countries, due to its high cloud point. 3) Lower long-term storage stability. The biodiesel becomes rancid due to oxidation and bacterial air. This rancidity process produces aldehydes, ketones and acids, which have strong and unpleasant odors. 4) It is required 1.1 liters of biodiesel to replace one liter of petroleum diesel, because of their lower calorific power. 5) High percent blends of biodiesel can soften and degrade certain types of elastomers and natural rubbers. In this case, precautions have to be taken concerning the materials in fuelling system. 6) Biodiesel may dilute the lubricating oil of engines. 7) The biodiesel produces more NO_x emissions than Petro diesel- a comparison of the emissions from biodiesel and Petro diesel is shown in table 4.

1.8.3 Advantages Of Bio-Diesel

Biofuels are seen as a more sustainable alternative to conventional petrol and diesel derived from fossil fuels because they come from renewable sources, which also absorb carbon dioxide (CO₂), although CO₂ will be emitted because of energy used in the harvesting and production process. Studies indicate that the

overall CO₂ savings from biofuels compared to conventional petrol and diesel vary between 20% to 70% depending on the type of crop and the energy consumed in growing, harvesting, transporting and processing the crop into a fuel.

- Biodiesel is the comparatively very clean and environmentally friendly only alternative fuel
- Biodiesel runs in any conventional unmodified diesel engine. It can be stored anywhere that petroleum diesel fuel is stored.
- Biodiesel can be used alone or mixed in any ratio with petroleum diesel fuel.
- Studies have found that the lifecycle production and use of biodiesel produces approximately between 80-100% less carbon dioxide and almost 100% less Sulphur dioxide emissions.
- β Combustion of biodiesel alone provides over a 90% reduction in total unburned hydrocarbons and a 75-90% reduction in aromatic hydrocarbons.
- Biodiesel further provides significant reductions in particulates and carbon monoxide than petroleum diesel fuel.
- Based on Ames Mutagenicity tests, biodiesel provides a 90% reduction in cancer risks.
- Biodiesel is 11% oxygen by weight and contains no sulphur. The use of biodiesel can extend the life of diesel engines because it is more lubricating than petroleum diesel fuel while fuel consumption, ignition, power output and engine torque are unaffected.
- Biodiesel is safe to handle and transport because it is as biodegradable as sugar, 10 times less toxic than table salt and has a high flashpoint of about 125C compared to petroleum diesel fuel, which has a flash point of 55C.
- Biodiesel can be made from renewable oilseed crops such as soybeans, rapeseed, cottonseed and mustard seed and non-edible oilseeds.

1.8.4 Process Description

The biodiesel is produced by transesterification of oil using methanol (alcohol) and NaOH (catalyst). The process steps are:

1) The vegetable and waste cooking oils are received. They are transported to the plant with trucks.

- 2) The oils are stored in outside tanks of the plant.
- 3) Drying and pretreatment of the oil.
- 4) The oil transesterification. The reactor is scheduled by 8000 hours per year, with a daily biodiesel production of 200 tons per day. The process starts with the refined oil. In the reactor, the oils are mixed with the methanol, in excess, NaOH (catalyst)
- 5) The reaction products are neutralized with a mineral acid. Methanol in excess is evaporated, and then condensed and stored to be reused in the next cycle.
- 6) The biodiesel is stored in tanks with nitrogen coverage to avoid its oxidation. The truck load is performed under nitrogen injection to avoid its degradation in transport.

1.9 ESSENTIAL OILS

Essential oils are the concentrated aromatic oils of plant leaves, flowers, seeds, bark, roots, and the rinds of some fruits. They vary in strength but are always very potent, and often smell best when diluted (as in other oils, colognes, and shampoos). Those essential oils obtained from trees are generally produced by a lengthy steam distillation process applied to either the chopped wood or the leaves and branch ends of the tree

1.10 ESSENTIAL OIL CATEGORIES

Most essential oil scents can be classified into the following categories:

1.10.1 Camphoraceous

A camphoraceous scent is one that's similar to camphor; a strongly aromatic, almost medicinal scent. Camphoraceous essential oils include eucalyptus, frankincense, hyssop, marjoram, rosemary, sage and, of course, camphor.

1.10.2 Floral

Essential oils derived from flowering botanical sources are referred to as floral scents. These essential oils include clary sage, chamomile, geranium, jasmine, juniper berry, lavender, rose, and ylangylang.

1.10.3 Mint

Herbs in the mint family are strongly aromatic, and the scent has long been revered by herbalists. In fact, in Greek mythology, mint is referred to as "the herb of hospitality." One of the first known uses of mint was as an air deodorizer.

Essential oils with a mint scent include pennyroyal, peppermint, spearmint and wintergreen, among others.

1.10.4 Musky

Musky essential oils have robust, earthy scents that are particularly penetrating and titillating to our sense of smell. These include myrrh, patchouli and citronella.

1.10.5 Spicy

Aromatic and invigorating, spicy essential oils can be livening up any room. Essential oils with this type of scent include anise, basil, cinnamon, ginger, nutmeg, oregano, tea tree, thyme, and more.

1.10.6 Sweet

One of the most popular scent categories, our sweet-scented oils include citronella, grapefruit, lemongrass, lemon, lime, orange and tangerine.

1.11 COMMONLY USED TYPES

Of the hundreds of oils available, some of the most popular essential oils include:

1.11.1 Clary Sage

May help to relieve hot flashes and promote sleep

1.11.2 Eucalyptus

An ingredient in steam inhalations to clear congestion and colds

1.11.3 Lavender

Often used for relaxation and to improve sleep

1.11.4 Lemon Oil

Lemon oil is commonly used in the kinds of commercially available products you encounter every day. If you walk down the aisles of any grocery store, you'll find everything from household cleaner to hand soap to flavored sparkling water with the essence of lemon. As is the case with many citrus oils, the scent closely mimics that of the fruit from which it's derived: bright, light, zesty, and clean.

1.11.5 Peppermint

Used for headaches and other types of pain

1.11.6 Sweet orange oil

In studies, it reduced anxiety when it was inhaled, and when applied topically, it slowed down participants' pulse rates and breathing rates, while they also reported feeling more cheerful and vigorous.

1.11.7 Rosemary

A stimulating scent said to boost attention and focus

1.11.8 Tea Tree

Used as for fungal skin infections and as a spot treatment for acne

1.11.9 Cinnamon oil

If lemon oil is bright, cool, and invigorating, cinnamon oil is its opposite: sweet and spicy, musky and warm. For me, cinnamon conjures up a distinct mixture of sexy exoticness and cozy familiarity, which makes sense because it's both a Far East import and a spice drawer mainstay.

Texas Oil is the naturally occurring essential oil from the wood of the native Texas Cedar (*Juniperus Mexicana*). The oil is recovered through the physical separation process of partial pressure steam distillation

1.12 TRANSESTERIFICATION

This process changes the molecular structure of lipid molecules and thus the physical properties. Although even refined pure plant oil (PPO) can be directly used in refitted diesel engines, biodiesel, which is created by a transesterification step, is very similar to fossil diesel and thus can be consumed in common diesel engines which are refitted with only small efforts.

Transesterification is also called alcoholysis, is the process by which the refined oil molecule is "cracked" and the glycerine is removed, resulting in glycerine soap and methyl or ethyl esters (biodiesel). Organic fats and oils are triglycerides which are three hydrocarbon chains connected by glycerol. The bonds are broken by hydrolyzing them to form free fatty acids. These fatty acids are then mixed or reacted with methanol or ethanol forming methyl or ethyl fatty acid esters (monocarbon acid esters).

The mixture separates and settles out leaving the glycerine on the bottom and the biodiesel (methyl-, ethyl ester) on the top. Now the separation of these two substances has to be conducted completely and quickly to avoid a reversed reaction.

These transesterification reactions are often catalyzed by the addition of an acid or base. For the transesterification process, mainly the alcohols methanol and ethanol are used. Theoretically, transesterification can be also processed with higher or secondary alcohols. Considering wide variety of oils and fats that can be used to produce biodiesel, there is a greater range in the characteristics of biodiesel fuels than for ethanol fuel. Ethanol is actually one very specific molecule, whereas biodiesel is a mix of molecules that varies somewhat, depending on the initial oil or fat source used to produce the fuel.

1.13 PITHECELLOBIUM DULCE SEED OIL

Pithecellobium dulce, commonly known as Manila tamarind, Madras thorn, or camachile, is a species of flowering plant in the pea family, Fabaceae, that is native to the Pacific Coast and adjacent highlands of Mexico, Central America, and northern South America. It is also sometimes known as monkeypod, but that name is also used for several other plants, including *Samanea saman*. It is an introduced species and extensively naturalized in the Caribbean and Florida, as well as the Philippines and Guam via the Manila galleons. It has also been introduced to Thailand and South Asia. It is considered an invasive species in Hawaii.

The *Pithecellobium dulce* Seed (*Zingiber officinale*) is a herbaceous perennial aromatic plant belongs to the family Zingiberaceae, mostly distributed in East Asia and tropical Australia, the rhizomes of which are used as a spice. In Indonesia ginger was usually used as a seasoning for dishes, an ingredient for beverage and a source of medicines. In the fields of medicine, ginger was used for treating various diseases such as colds, intestinal worms, gout, bronchitis, asthma, heart disease, and can be used to improve digestion. Beside raw usage, ginger can be processed to obtain the essential oil. The essential oil derived from ginger has many usage and advantages such as proven to be an active antimicrobial not only for gram-positive bacteria but also for gram-negative bacteria and proven having an antioxidant ability so it can be used as natural food preserver.

1.13.1 Countries where it's found

The plant is grown in India, China, and France. The plant is also found to grow in Madagascar, Brazil, and few Asian regions. Harvesting Information Celery Seedplant is best harvested after 10 months of plantation. It is a perennial plant growing up to 9 feet.

1.13.2 History of the Plant

The plant has been used since the 18 century in India. It is an herbaceous plant with long, elongated and slender stems each with a terminal flowering top. Ancient aroma therapists used the oil to reduce stress and to improve blood circulation. Indian soap makers have used this oil for decades.

1.13.3 Extraction Process

The oil is extracted from the **Pithecellobium dulce** Seed plant by steam distillation. The oil is amber yellow in colour with fresh, citrus odour.



Fig: 1.1: *Pithecellobium dulce* Seed oil

1.13.3.1 Steam Distillation Process

Steam distillation process was carried out in a custom sized distillation device coupled with an electrical steam boiler. Electrical steam boiler used 220 volts, 16-amperes worth electric current and capable of producing 20 bars (max) at 214°C of steam. The distillation device was equipped with custom sized condenser and glass decanter to separate oil from condensate. The scheme of the apparatus can be seen in Figure 1. The volume and diameter of distillation chamber were 16.5 liters, 256 mm respectively and using stainless steel with the thickness of 2 mm as the material. The distillation chamber was also equipped with a steam distributor which is mounted 700 mm from the bottom of the chamber and grating which is mounted 300 mm from the steam distributor as the place to put ginger rhizome. About 500 grams pre treated rhizomes were placed on the grating inside the distillation chamber and 1.5 bar steam were used with the flow rate of 0.35; 0.55; 0.76; and 1.16 ml/s as the variable. These process conditions were based on the capacity of apparatus. The distillation process was maintained for 8 hours with measurement of the oil obtained in every hour. This process was repeated twice.

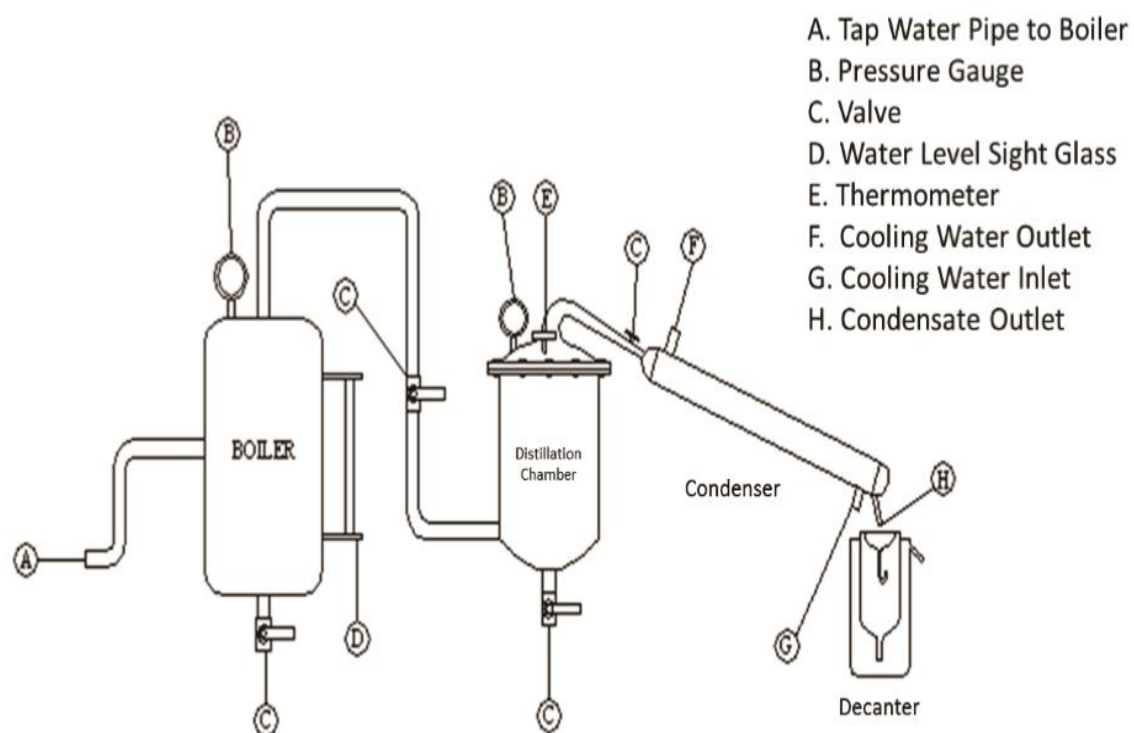


Fig.1.2: *Pithecellobium dulce* Seed Steam distillation apparatus

1.13.3.2 Hydro distillation Process

To investigate the maximum oil content in ginger rhizomes, a hydrodistillation process was carried out at standard Clevenger-type apparatus. A 3000 ml flask was used as boiling flask and 1:6 of pre treated ginger rhizomes: solvent (tap water) were used. The process was maintained for 24 hours and yielded 2.65% of the oil

CHAPTER II

LITERATURE REVIEW

Remiszewska.E et al, The author proposed a novel micro analytical system based on absorption photometry for urea determination in small volume biological samples is described. The developed micro system with built-in micro reactor with urea immobilised on its surface was fabricated using low temperature co-fired ceramics (LTCC) technology. For detection of the ammonium ions – product of urea hydrolysis, the modified Berthelot's reaction was applied and conditions of this reaction were optimised in a way to be suitable for analysis in micro systems and for particular application,

Rafal Sala et al, This work tried to identify the influence of dosing vaporized urea solution in a selective catalytic reduction (SCR) system. In the SCR method, optimising the urea evaporation and mixing properties can significantly improve the NO_x conversion efficiency in the catalyst. It can also exert a positive effect on the uniformity of NH₃ concentration distribution across the catalyst face. The concept of an electrically evaporated urea-dosing system was investigated and it was found that urea pre-heating prior to introduction into the exhaust gas is favourable for enhancing NO_x removal under steady-state and transient engine operation.

Kasim Mohammed Hello et al, The author proposed a new treatment has been demonstrated for urea to synthesis solid-state form of urea sulfate onto silica extracted from rice husk ash via 3-(chloropropyl)triethoxysilane. The 3-(chloropropyl)triethoxysilane was immobilized onto silica at room temperature to functionalize the silica with chloride end groups. The chloride groups were reacted with urea by a nucleophilic substitution reaction. The resulting silica with urea (which had amine end groups) was sulfated with diluted sulfuric acid to produce a novel solid state form catalyst designated.

Jiranart Jeenchay et al, The purposes of this work are to design conceptual processes of ammonia/urea plants and to do economic analysis and feasibility study. This paper consists of two main parts; simulation of ammonia/urea plants and techno economic analysis. First, the simulation software PRO/II is used to simulate the base-case process. From the base-case studies the principal route of urea production is originally from carbon dioxide and ammonia, which are

produced from nitrogen and hydrogen. All conditions and input parameters are obtained from petrochemical industry in Thailand. Finally, techno economic analysis is a key of feasibility study to estimate investment cost and the profitability of project.

Qian Wang et al, They attempt, the catalytic converter for SCR have been researched from these respects of carrier, coating and package. A catalyst has been designed based on these characteristics of carrier, coating, package . The reasons for the crystallization of urea in pipe are analyzed, in order to eliminate the crystallization the layout of exhaust pipe is optimized; and the best nozzle installation location is confirmed. To prove the performance of catalyst and the result of optimization of exhaust pipe layout, verification experiments are conducted. These results of experiment can meet European IV emission regulations.

Howard L et al, Urea-selective catalytic reduction (SCR) has been a leading contender for removal of nitrogen oxides (deNO_x) from diesel engine emissions. Despite its advantages, the SCR technology faces some critical detriment to its catalytic performances such as catalyst surface passivation (caused by deposit formation) and consequent stoichiometric imbalance of the urea consumption. Deposit formation deactivates catalytic performance by not only consuming part of the ammonia produced during urea decomposition but also degrading the structural and thermal properties of the catalyst surface. We have characterized the urea thermolysis with and without the urea-SCR catalyst using both spectroscopic (DRIFTS and Raman) and thermal techniques (thermal gravimetric analysis (TGA) and differential scanning calorimetry (DSC)) to identify the deposit components and their corresponding thermal properties

Muhammad khristanto et al, A study on the effects of urea injection timing and wall temperatures to predict NO_x reduction efficiency is simulated using a commercial code of STAR-CCM+. In this study, the experimental and simulations work to obtain constant and stable conditions in the SCR system were conducted. Because the constant condition can optimize the uniformity of urea distribution in the system. This data explains if the distribution of gas reaction in simulation was unstable below 20s of time.

Karthickeyan Viswanathan et al, From the present experimental investigation, the ureabased selective reduction technique along with catalytic converter was considered as the prominent technique for the reduction of engine exhaust emissions in diesel engine. B25 biodiesel sample showed lower CO, HC, NO_x, and smoke emissions with SCR and CC setup than conventional engine (without SCR and CC). Thus, SCR and CC technique along with B25 biodiesel sample was considered as the promising parameter for emission reduction in diesel engine.

Ghosh.S et al, Injection of aqueous solutions of urea in the tail pipe of a diesel engine fuelled with Pongamia pinata methyl ester (PPME) for the reduction of oxides of nitrogen (NO_x) was carried out in a four stroke, single cylinder, water cooled, constant speed diesel engine. Four observations were made for various concentration of urea solution 0%, 10%, 20%, and 30% by weight with different flow rates of urea solution as reductant by fitting Marine Ferromanganese nodule as SCR catalyst which improves the chemical reactions. 64% NO_x reduction achieved with the urea flow rate 0.60 lit/hr, 30% concentration of urea solution and marine ferromanganese nodule as SCR.

Julia M.C et al, .Schitosan is an adequate material for the preparation of potentiometric urea biosensors based on coupling of enzymatic membranes with all-solid state PVC membrane ammonium electrodes with nonactin as sensor. The characteristics of response of these urea biosensors depend on the procedure used for enzyme immobilization. The biosensors with urea immobilized on chitosan membranes by adsorption followed by cross linking with dilute aqueous glutaraldehyde solutions, showed the best characteristics of response, including the longest lifetime (more than 2 months).

Husnawan M,et al in this paper they have concluded that by using vegetable oil based additive combined with metal based additive. Test was conducted using biodiesel from palm blended with diesel, the results shown that fuel burns better and excess air reduces the CO content.

Pradip kumar B,et al in this paper they have explained how to overcome the problems associated with biodiesel i.e., A fuel additive generally improves the combustion efficiency and reduces the pollution. Important advantage of nanoparticles is its size because there is no chance for fuel injector and filter clogging as in case of micron sized particles.

Ganesh D, et al In this they have concluded that reduction in CO emission was observed with cobalt oxide and magnalium nano fuel additive. Cobalt oxide showing 50% reduction at 75% load, because cobalt oxide acts as an oxygen buffer and donates surface lattice oxygen.

S.Thiyagarajan, et al From this paper they have concluded that the use of high and low viscosity biofuels in CI engines can adversely affect engine performance due to poor mixture formation and longer ignition delay. However, FIF could alleviate the challenges associated high and low viscosity biofuels. The difficulty associated with high viscosity is addressed through fuel ionisation which improves fuel atomisation and air-fuel mixing while the ignition delay is reduced with low viscosity biofuels due to shorter physical delay which in turn reduces NO emission.

CHAPTER III

AIM AND SCOPE OF THE PROJECT

3.1 AIM

To compare the performance combustion and emission characteristics of DI engine using Nano-additives (nickel oxide) and (Cerium Oxide) as a catalyst in Pithecellobium dulce Seed Oil biodiesel blends with pure diesel and to determine the best combination of biodiesel blend for optimum performance and Emission.

3.2 SCOPE OF WORK

To Determine the parameters such as Specific fuel consumption (SFC) and brake thermal efficiency (BTE), emission characteristics such as Nitric-Oxide, Oxygen, Carbon-dioxide, Hydrocarbon, and Carbon-mono oxide at different loads and brake power for pure diesel and various combination of Pithecellobium dulce Seed oil separately and mixed with CeO_2 and NiO .

The objective of this project is to create a new fuel that can be used in a diesel engine as a fuel. The fuel is created by making an emulsion of diesel and water by using a suitable surfactant. The emission and performance characteristics of the engine are thus noted down and put in tabular form. Then the engine is run with regular diesel fuel and same observations are taken.

CHAPTER IV

METHODOLOGY AND EXPERIMENTAL WORK

4.1 METHODOLOGY

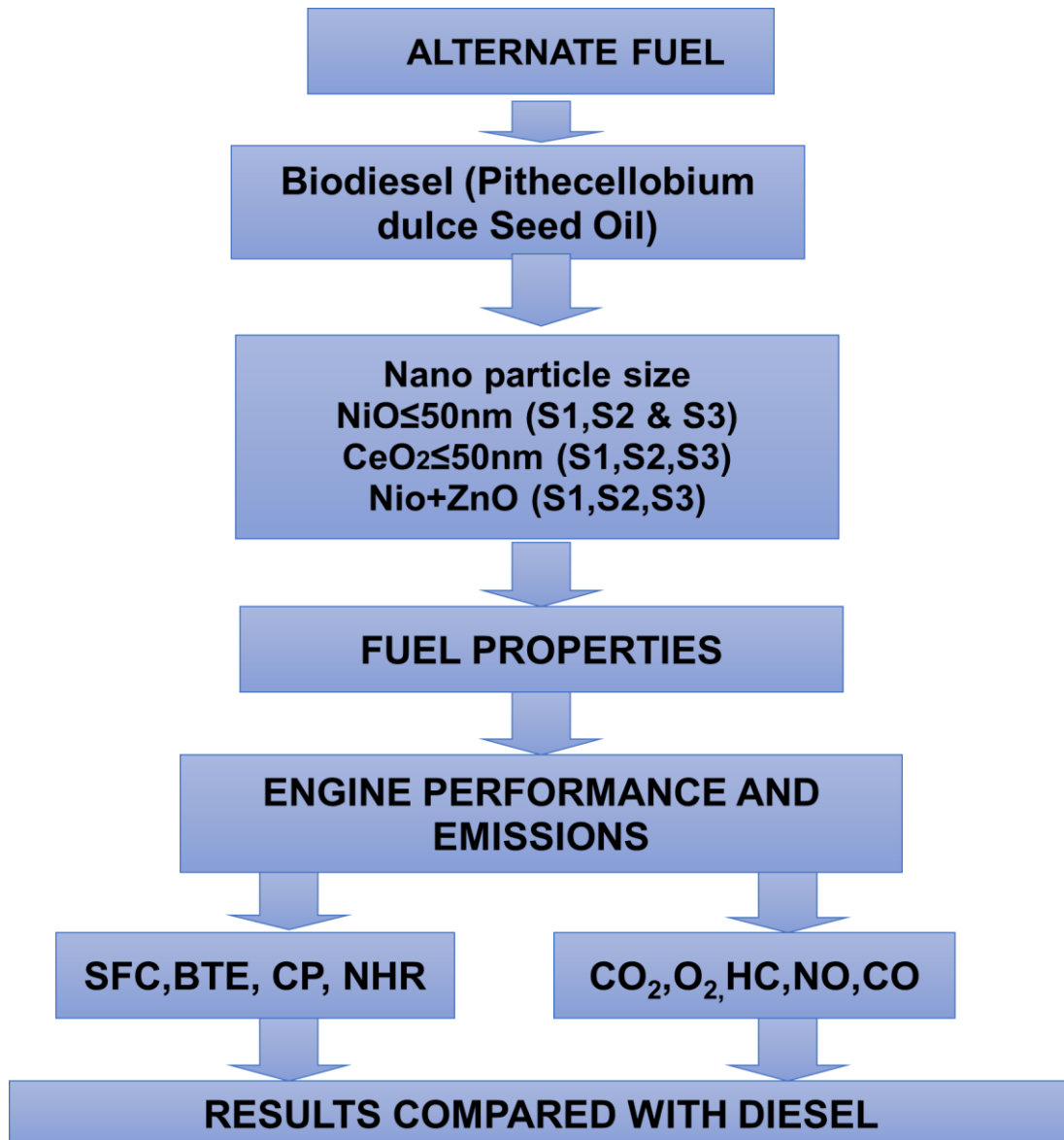


Fig.4.1: Methodology

4.2. PITHECELLOBIUM DULCE SEED BIOFUEL

Pithecellobium dulce Seed Oil was esterified using the transesterification method. The base catalysed transesterification process is the reaction of a triglyceride (Fat/oil) with an alcohol to form ester and glycerol in the presence of a base catalyst, which in most of the cases is either sodium hydroxide (NaOH) or Potassium Hydroxide (KOH). This process brings the fuel properties closer to that of diesel and reduces its viscosity. The oil properties were checked after the oil was esterified and the free fatty acid value is 0.846%

Table: 4.1 Properties of Pithecellobium dulce Seed Oil

S. No.	Properties	Results
1	Density	0.910g/CC
2	Kinematic viscosity	1.922cSt
3	Moisture content	0.073%
4	Flash point by PMCC method	94°C
5	Fire point by PMCC method	109°C
6	Calorific value	8213.611cal/g

4.2.1 Transesterification process

The transesterification process was followed by magnetic stir ration which is a common technique used to mix liquids. A magnetic mixer is a laboratory device that employs a rotating magnetic field to cause a stir bar (also called “flea”) immersed in a liquid to spin very quickly at a speed of 1200 rpm at 40 deg cel, thus stirring it. The rotating field created by a rotating magnet placed beneath the vessel with the liquid. Totally five samples namely B10, B20, and B30, were prepared. B10 contains a mixture of 90% of diesel, 10% of Pithecellobium dulce Seed biodiesel and cerium oxide and nickel oxide nano additive 100 ppm. B20 contains a mixture of 80% of diesel, 20% of Pithecellobium dulce Seed biodiesel and 100ppm of cerium oxide and nickel oxide nano additive. B30 contains a

mixture of 70% of diesel, 30% Pithecellobium dulce Seed biodiesel and 30 ppm of cerium oxide and nickel oxide nano additive.

Table: 4.2 Transesterification Report of Pithecellobium dulce Seed biodiesel

S. No.	Parameters	Results
1	Free fatty acid	0.191%
2	Catalyst (NaOH) quantity	5 grams
3	Oil to methanol molar ratio	1:6
4	Temperature	60°C
5	Reaction time	90 minutes
6	Yield	91.7%

4.2.2 Nanoparticle additives

Cerium Oxide (CeO_2 and Nickle Oxide NiO) photography view as shown in fig.4.2. The particles are around ten nm in diameter or smaller and are typically coated with wetter molecules, like monounsaturated fatty acid, to stop agglomeration. Nanoparticles will have terribly high thermal conductivities and their heat transfer properties. They determined a thermal conduction sweetening of 13.88–28.46% at 0.3% volume concentration within the temperature vary of 25–60°C



Figure.4.2: Nanoparticles (Cerium Oxide (CeO_2 and Nickle Oxide NiO)

4.3 EXPERIMENTAL SETUP

A single-cylinder has 4-stroke, direct injection Kirloskar TV1 diesel engine with a maximum rated output of 5.20 kW at 1500 rpm was utilized to obtain the set of experimental data required. The engine has a compression ratio of 17.5. The engine has a swept volume of 661.45 (cc), bore diameter of the engine is 87.50 mm and stroke length of 110.00 mm. Injection pressure is 210 bar maintained constantly throughout the process.



Fig 4.3: Engine set up

4.3.1 Engine details

IC Engine set up under test is Research Diesel having power 3.50 kW @ 1500 rpm which is 1 Cylinder, four strokes, Constant Speed, Water Cooled, Diesel Engine, with Cylinder Bore 87.50(mm), Stroke Length 110.00(mm) Connecting Rod length 234.00(mm), Compression Ratio 18.00, Swept volume 661.45 (cc).

4.3.2 Combustion Parameters

Specific Gas Constant (kJ/kg K) = 1.00, Air Density (kg/m³) = 1.17, Adiabatic Index: 1.41, Polytrophic Index: 1.15, Number of Cycles: 10, Cylinder Pressure Reference: 6, Smoothing 2, TDC Reference: 0

Table: 4.3 Engine Specifications

Product	VCR Engine test setup 1 cylinder, 4 stroke, Diesel with EGR (Comp.)
Engine	Make Kirloskar, Type 1 cyl., 4 stroke Diesel, water cooled, power 3.5kW at
	1500rpm, stroke 110mm, bore 87.5mm. 661cc, CR17.5, Modified to VCR
	Engine CR 12 to 18. With electric start arrangement, battery and charger
Dynamometer	Type eddy current, water cooled,
Propeller shaft	With universal joints
Air box	M S fabricated with orifice meter and manometer
Fuel tank	Capacity 15 lit with glass fuel metering column
Calorimeter	Type Pipe in pipe
EGR	Water cooled, SS, Range 0-15%
Piezo sensor	Range 5000 PSI, with low noise cable
Crank angle sensor	Resolution 1 Deg, Speed 5500 RPM with TDC pulse.
Data acquisition device	NI USB-6210, 16-bit, 250kS/s.
Piezo powering unit	Model AX-409.
Temperature sensor	Type RTD, PT100 and Thermocouple, Type K
Temperature transmitter	RTD PT100, Range 0–100oC,3 No's; Thermocouple, Range 0-1200oC, 2 No's
Load indicator	Digital, Range 0-50 Kg, Supply 230VAC
Load sensor	Load cell, type strain gauge, range 0-50 Kg
Fuel flow transmitter	DP transmitter, Range 0-500 mm WC

Table: 4.4 Performance Parameters

Orifice Diameter (mm)	20.00
Orifice Coefficient. Of Discharge	0.60
Dynamometer Arm Length (mm)	185
Fuel Pipe dia (mm)	12.40
Ambient Temp. (deg C)	27
Pulses Per revolution	360

4.3.3 specification of gas analyzer

4.3.4. Measuring ranges:

Oxygen (O₂) 0 - 25,00 % vol

Carbon monoxide (CO) 0 – 15,00 %

Carbon dioxide (CO₂) 0 – 20,0 %

Carbon hydride (HC) 0 - 20000 ppm n-hexane

Nitrogen monoxide (NO) 0 - 2000 ppm

Excess Air calculated according to Brettschneider

Temperature -40 ... +650°C

Rounds per minute 400 ... 10000 U/min

4.3.5. Precision:

Oxygen (O₂) $\pm 0,1$ % or $\pm 3\%$

Carbon monoxide (CO) $\pm 0,06$ % or $\pm 5\%$ of measured value

Carbon dioxide (CO₂) ± 0.5 % or $\pm 5\%$ of measured value

Carbon hydride (HC) ± 12 ppm or $\pm 5\%$ of measured value

Nitrogen monoxide (NO) ± 5 ppm or ± 5 % of measured value

Temperature $\pm 1\%$ (T<150°C) + 2% (T<250°C) $\pm 3\%$ (T>250°C)

rounds per minute $\pm 1\%$

4.3.6. Resolution:

Oxygen (O₂) 0,01 %

Carbon monoxide (CO) 0,01 %

Carbon dioxide (CO₂) 0,1 %

Carbon hydride (HC) 1 ppm

Nitrogen monoxide (NO) 1 ppm

Carbon hydride (HC) 1 ppm

Nitrogen monoxide (NO) 1 ppm

Temperature 0,1°C

Rounds per minute 1U/min (<6000) or 10U/min (>6000)

4.3.7 Procedure of Experiment

- The filters of the engine were replaced and the injectors were cleaned and calibrated according to the desired pressure.

STEP 1 (ENGINE TEST BY PITHECELLOBIUM DULCE SEED OIL)

Sample 1 B10

Sample 2 B20

Sample 3 B30

STEP 2 (ENGINE TEST BY PITHECELLOBIUM DULCE SEED OIL WITH CeO₂)

B10 + 100 ppm CeO₂

B20 + 100 ppm CeO₂

B30 + 100 ppm CeO₂

STEP 3 (ENGINE TEST BY PITHECELLOBIUM DULCE SEED OIL WITH NiO)

B10 + 100 ppm NiO

B20 + 100 ppm NiO

B30 + 100 ppm NiO

STEP 4 (ENGINE TEST BY PITHECELLOBIUM DULCE SEED OIL WITH NiO)

B10 + (100 ppm CeO₂ + 100 ppm NiO)

B20 + (100 ppm CeO₂ + 100 ppm NiO)

B30 + (100 ppm CeO₂ + 100 ppm NiO)

Fig.4.4.Test samples

- The AVL gas analyzer and smoke meter were installed. The input to the gas analyzer was taken from the exhaust port of the engine.
- The fuel tank was then filled with diesel and the engine was run.
- The engine was run at various loads of the dynamometer – 0,3,6,9,12.
- kgs and respective readings were taken for fuel consumption/ sec.
- The readings of gas analyzer and smoke meter were noted in each case.
- After all the readings were taken, the leftover diesel was drained out of the
- tank and emulsion was poured.

- Same steps were taken and the readings were noted down for the emulsion.
- Before using the next emulsion the engine was again run with diesel so that
- the results are not biased.
- After taking all the observations graphs were plotted to compare
- the performance characteristics and emission characteristics of the engine in
- case of diesel and emulsion.
- 10. Before using the next emulsion the engine was again run with diesel so that

the results are not biased.

4.4. AVL GAS ANALYSER

AVL gas analyzer for measurement of CO, HC, CO₂, O₂ and lambda. Pollution testing machines. Our customers are workshops, automobile engineering colleges, IITs, NITS, RTA, all engine manufacturers. It is a portable type and used to measure concentration of SO₂, NO, CO, CO₂ and O₂ from stack or boiler emission gases, in which SO₂, NO, CO and CO₂ are measured by micro-flow infrared sensors and O₂ by electrochemical sensor, with optional gas temperature, pressure, velocity etc, calculating combustion efficiency, lambda, etc.



Fig 4.5: Gas Analyser

A Gas analyzer measures trace gases by determining the absorption of an emitted infrared light source through a certain air sample. Trace gases found in the Earth's atmosphere get excited under specific wavelengths found in the infrared

range. The concept behind the technology can be understood as testing how much of the light is absorbed by the air. Different molecules in the air absorb different frequencies of light. Air with lots of a certain gas will absorb more of a certain frequency, allowing the sensor to report a high concentration of the corresponding molecule. Infrared gas analyzers usually have two chambers, one is a reference chamber while the other chamber is a measurement chamber. Infrared light is emitted from some type of source on one end of the chamber, passes through a series of chambers that contains given quantities of the various gases.

4.5 SONICATION PROCESS

Sonication is the act of applying sound energy to agitate particles in a sample, for various purposes such as the extraction of multiple compounds from plants, microalgae and seaweeds. Ultrasonic frequencies (>20 kHz) are usually used, leading to the process also being known as ultrasonication or ultra-sonication. In the laboratory, it is usually applied using an *ultrasonic bath* or an *ultrasonic probe*, colloquially known as a *sonicator*. In a paper machine, an ultrasonic foil can distribute cellulose fibres more uniformly and strengthen the paper.

Sonication has numerous effects, both chemical and physical. The chemical effects of ultrasound are concerned with understanding the effect of sonic waves



Fig 4.6: Sonication process

on chemical systems, this is called sonochemistry. The chemical effects of ultrasound do not come from a direct interaction with molecular species. Studies have shown that no direct coupling of the acoustic field with chemical species on a molecular level can account for sonochemistry or sonoluminescence. Instead, in

sonochemistry the sound waves migrate through a medium, inducing pressure variations and cavitations that grow and collapse, transforming the sound waves into mechanical energy.

4.6 EXPERIMENTAL TEST

A single-cylinder has 4-stroke, direct injection Kirloskar TV1 diesel engine with a maximum rated output of 5.20 kW at 1500 rpm was utilized to obtain the set of experimental data required. The engine has a compression ratio of 17.5. The engine has a swept volume of 661.45 (cc), bore diameter of the engine is 87.50 mm and stroke length of 110.00 mm. Injection pressure is 210 bar maintained constantly throughout the process.



Fig 4.7: Engine Test

CHAPTER V

RESULTS AND DISCUSSION

Notation Used for Result and Discussion

B10 – 10% Biodiesel + 90% Diesel

B20 - 20% Biodiesel + 80% Diesel

B30 - 30% Biodiesel + 70% Diesel

NP1 – 100 ppm Cerium Oxide (CeO_2)

NP2 – 100 ppm Nickel Oxide (NiO)

MNP – Mixed Nano Particle (100 ppm Cerium Oxide + 100 ppm Nickel Oxide)

5.1BRAKE THERMAL EFFICIENCY

Table 5.1: Brake thermal efficiency in %

Load	D 100	B10	B20	B30	B10+ NP1	B20+ NP1	B30+ NP1	B10+ NP2	B20+ NP2	B30+ NP2	B10+ MNP	B20+ MNP	B30+ MNP
0%	2.45	3.39	1.49	0.97	0.54	3.92	2.85	1.83	1.5	2.43	1.49	1.25	1.50
25%	16.49	15.94	15.86	14.02	14.41	18.21	13.97	13.59	14.71	14.85	14.90	15.86	14.58
50%	22.75	27.38	23.5	22.49	21.82	25.14	25.05	21.18	24.14	22.14	24.56	20.37	20.63
75%	31.71	29.07	27.53	26.51	25.46	31.42	26.22	24.52	27.9	26.22	28.70	25.28	27.90
100%	32.59	32.1	32.38	35.55	35.57	28.35	29.06	31.71	33.27	30.22	31.43	32.08	34.59

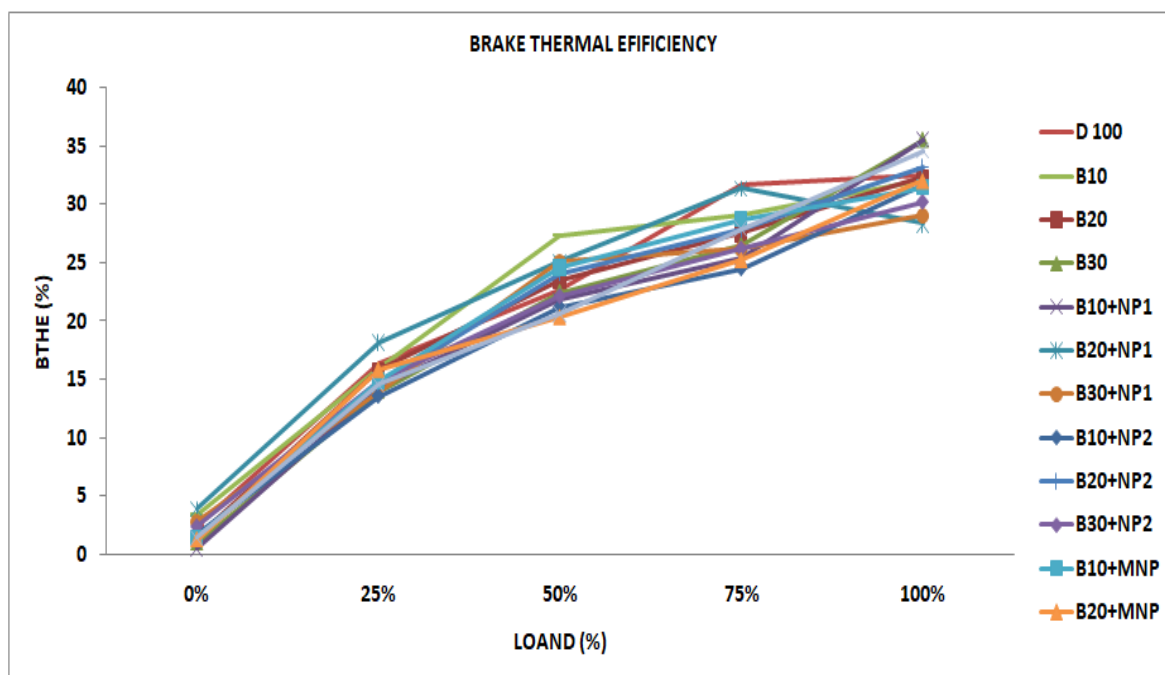


Figure.5.1: Load Vs Brake thermal efficiency

The graph for brake thermal efficiency with brake power for diesel and biodiesel blends is illustrated in Figure 5.1. Higher brake thermal efficiency is obtained for B20+NP1 compared with diesel due to higher viscosity and poor volatility for biodiesel, leads to reduced spray cone angle causes reduction in air entrainment during fuel-air mixing in the combustion chamber. At full load, the BTE obtained for D100, B10, B20, B30, B10+NP1, B30+NP1, B10+NP2, B20+NP2, B30+NP2, B10+MNP, B20+MNP, and B30+MNP are 32.59%, 32.01%, 32.38%, 34.55%, 28.82%, 29.06%, 31.71%, 32.37%, 30.22%, 31.43%, 32.08%, and 34.59% respectively, whereas for diesel it is 32.59%.

5.2 BRAKE SPECIFIC FUEL CONSUMPTION

Table 5.2: Specific fuel consumption in Kg/kWh

Load	D 100	B10	B20	B30	B10+ NP1	B20+ NP1	B30+ NP1	B10+ NP2	B20+ NP2	B30+ NP2	B10+ MNP	B20+ MNP	B30+ MNP
0%	2.48	2.62	3.97	4.15	2.42	3.05	3.11	4.87	5.94	3.65	4.31	5.14	5.96
25%	0.52	0.56	0.56	0.63	0.62	0.55	0.64	0.65	0.6	0.6	0.53	0.53	0.61
50%	0.38	0.32	0.38	0.4	0.41	0.42	0.35	0.42	0.37	0.4	0.36	0.37	0.43
75%	0.39	0.28	0.32	0.34	0.35	0.35	0.34	0.36	0.32	0.34	0.31	0.35	0.22
100%	0.2	0.31	0.13	0.29	0.41	0.35	0.32	0.28	0.25	0.26	0.41	0.37	0.28

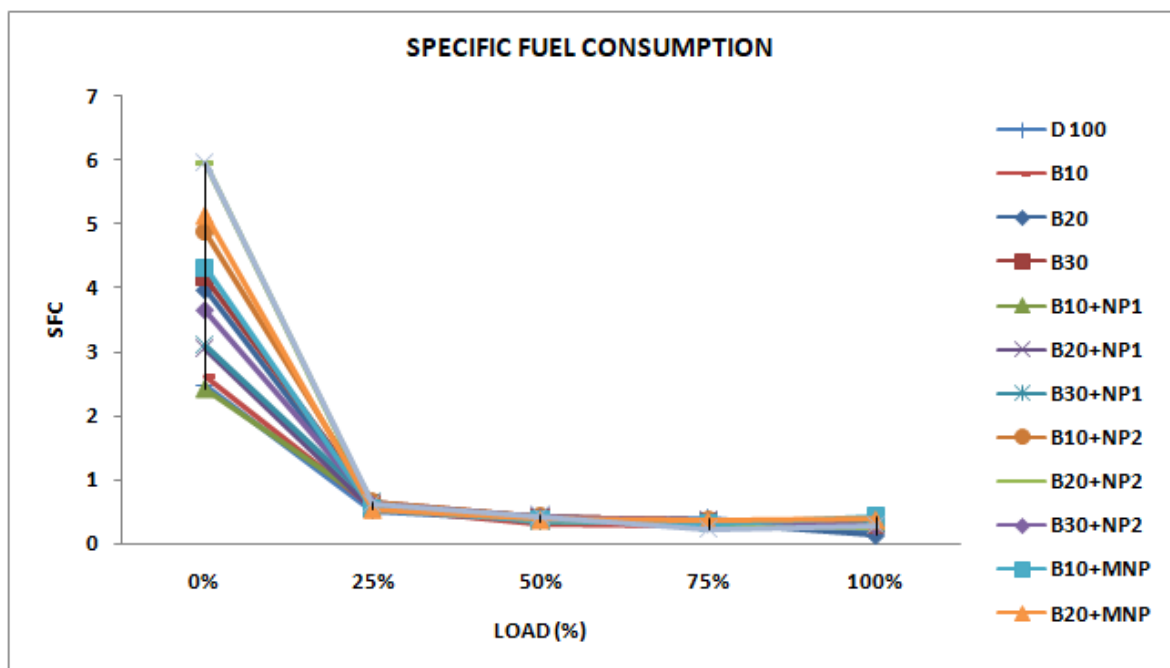


Figure.5.2: Load Vs Brake specific fuel consumption

Figure 5.2. represents the brake specific fuel consumption with brake power for diesel and biodiesel blends. The BSFC obtained for the fuel, B10, B20, B30,

B10+NP1, B30+NP1, B10+NP2, B20+NP2, B30+NP2, B10+MNP, B20+MNP, and B30+MNP is 0.31kg/kWh, 0.13kg/kWh, 0.29kg/kWh, 0.31kg/kWh, 0.41kg/kWh, 0.35kg/kWh, 0.32kg/kWh, 0.28kg/kWh respectively, whereas for diesel it is 0.20kg/kWh at full load. It is observed that at full load, the BSFC is increased for all biodiesel blends compared to diesel due to high viscosity and lower heating value of biodiesel and its higher blends. It is also observed that B20 has lower BSFC at full load conditions, resulting in better combustion compared with other biodiesel blends.

5.3 CARBON MONOXIDE EMISSION (CO)

Table 5.3 Emission in CO (ppm)

Load	D 100	B10	B20	B30	B10+NP1	B20+NP1	B30+NP1	B10+NP2	B20+NP2	B30+NP2	B10+MNP	B20+MNP	B30+MNP
0%	0.073	0.078	0.076	0.07	0.072	0.082	0.084	0.076	0.093	0.077	0.076	0.07	0.072
25%	0.072	0.075	0.075	0.068	0.065	0.079	0.08	0.068	0.082	0.076	0.075	0.068	0.065
50%	0.07	0.073	0.073	0.065	0.062	0.075	0.075	0.063	0.074	0.07	0.073	0.065	0.062
75%	0.067	0.07	0.07	0.062	0.054	0.069	0.069	0.061	0.065	0.068	0.07	0.062	0.054
100%	0.058	0.069	0.068	0.053	0.049	0.061	0.061	0.052	0.061	0.062	0.068	0.053	0.049

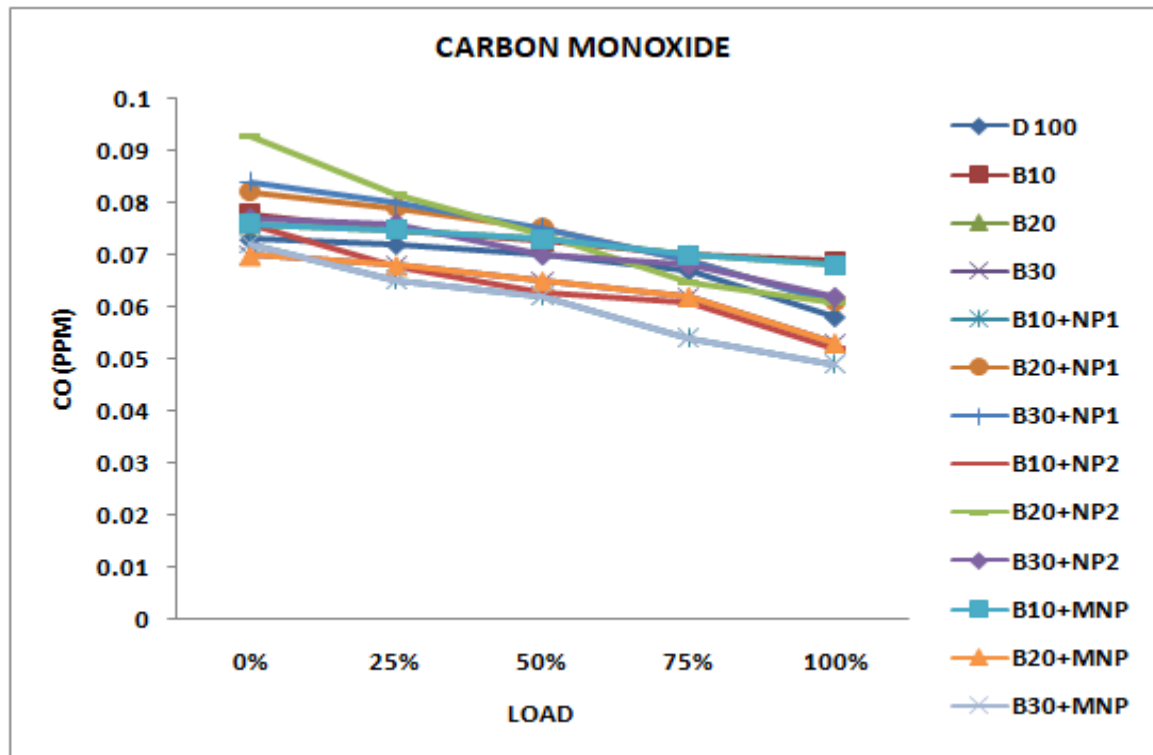


Figure.5.3: Load Vs Carbon monoxide

Carbon monoxide variation with brake power for diesel and biodiesel blends is presented in Figure 5.3. Generally diesel engine producing higher amount of carbon monoxide emission at low loads and giving lower values at higher loads. At full load, CO emission for B10, B20, B30, B10+NP1, B30+NP1, B10+NP2, B20+NP2, B30+NP2, B10+MNP, B20+MNP, and B30+MNP at maximum load is 0.069 ppm, 0.068 ppm, 0.053 ppm, 0.061ppm, 0.052ppm, 0.061ppm, 0.062ppm, 0.068ppm, 0.053ppm, and 0.049ppm respectively, and for diesel it is 0.058 ppm at full load. The reason for decrease in CO emission for biodiesel and its blends due to higher cetane number and more oxygen molecule present in the biodiesel resulting in complete combustion of the biodiesel at full load.

5.4 HYDROCARBON EMISSION (HC)

Table 5.4 HC Emission in (ppm)

Load	D 100	B10	B20	B30	B10+NP1	B20+NP1	B30+NP1	B10+NP2	B20+NP2	B30+NP2	B10+MNP	B20+MNP	B30+MNP
0%	53	55	57	58	53	54	55	56	58	60	52	53	55
25%	53	56	58	59	53	55	56	57	60	60	53	54	56
50%	53	58	60	62	54	58	58	58	61	62	53	55	57
75%	54	59	61	63	55	58	60	59	65	65	54	56	60
100%	67	62	63	65	56	59	62	64	68	69	55	60	65

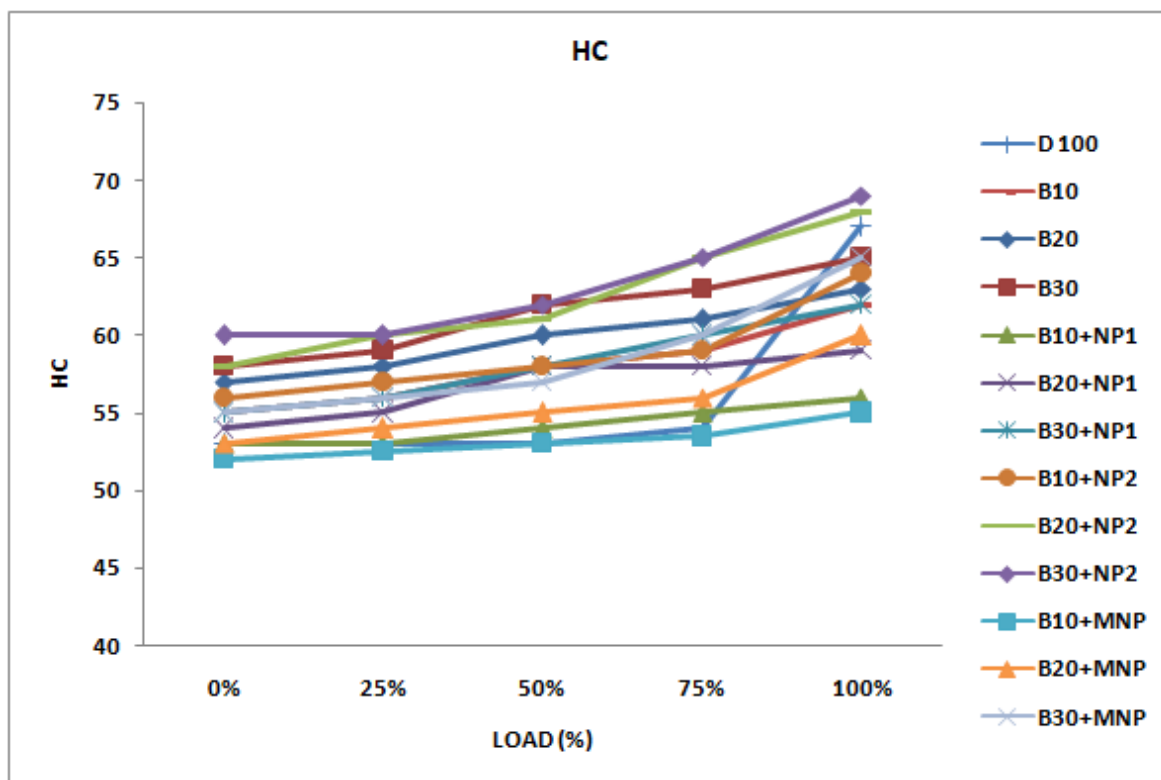


Figure.5.4: Load Vs Hydrocarbon

Variation of hydrocarbon emission with brake power for test fuels is presented in Figure 5.4. Hydrocarbon emission is mainly due to the presence of gaseous hydrocarbons in the relatively stagnant low temperature, boundary layer along the cylinder wall and in the cervices. It is noticed that the HC emissions are higher for WJB40 compared to diesel. The HC level B10, B20, B30, B10+NP1, B30+NP1, B10+NP2, B20+NP2, B30+NP2, B10+MNP, B20+MNP, and B30+MNP at maximum load is varies from 62ppm, 63ppm, 65ppm, 56ppm, 59ppm, 62ppm, 64ppm, 68ppm, 69ppm, 55ppm, 60ppm, and 65ppm at full load for diesel and from 67ppm. Due to poor atomization and vaporization characteristics of biodiesel blends B30+NP2, the HC may be increased for at higher loads as compared to diesel.

5.5 NITRIC OXIDE EMISSION (NO_x)

Table 5.5: NO_x Emission in ppm

Load	D 100	B10	B20	B30	B10+NP1	B20+NP1	B30+NP1	B10+NP2	B20+NP2	B30+NP2	B10+MNP	B20+MNP	B30+MNP
0%	138	54	58	59	59	56	29	41	197	58	52	56	29
25%	235	112	119	115	128	126	66	86	409	120	108	126	66
50%	432	200	204	213	242	234	144	173	386	124	222	249	144
75%	603	355	387	385	339	449	306	353	710	432	399	461	306
100%	1151	528	593	575	505	678	658	515	709	630	725	702	658

Oxides of nitrogen emission variation graph for diesel and biodiesel blends is depicted in Figure 5.5. Generally, NO_x emission is generated mostly from the nitrogen present in the incoming atmospheric air to the engine due to high combustion temperature during combustion process. At full load, higher NO_x emissions were observed for Waste Cooking Oil and Juliflora oil mixed oil blends compared to diesel. It is noticed that the nitrogen oxide emission were decreased at full load compared to diesel fuel. The reason for decrease in NO_x emission is due to the presence of more oxygen in biodiesel and its blends, leads to complete combustion of fuel. Hence more amounts of NO_x emissions were produced at higher loads. NO_x emission for the B10, B20, B30, B10+NP1, B30+NP1, B10+NP2, B20+NP2, B30+NP2, B10+MNP, B20+MNP, and B30+MNP operation is 528ppm, 593ppm, 575ppm, 505ppm, 678ppm, 658ppm, 515ppm, 709ppm, 630ppm, 725ppm, 702ppm, and 658ppm respectively and for diesel it is 1151ppm at full load.

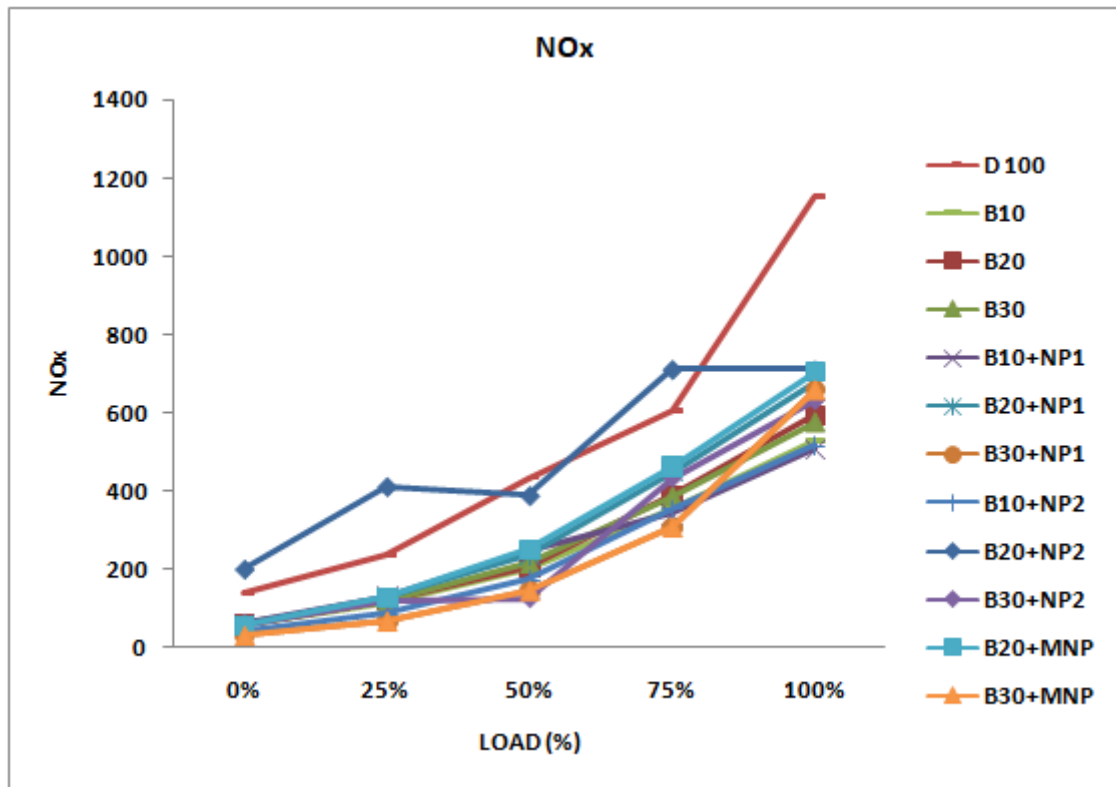


Figure.5.5: Load Vs Nitric oxide

5.6 CARBON DIOXIDE (CO₂)

Table 5.6 CO₂ Emission in (%)

Load	D 100	B10	B20	B30	B10+NP1	B20+NP1	B30+NP1	B10+NP2	B20+NP2	B30+NP2	B10+MNP	B20+MNP	B30+MNP
0%	2.09	1.02	0.94	1.14	0.91	0.87	0.9	0.87	1.18	1.47	1.32	1.09	0.64
25%	2.73	1.54	1.62	1.74	1.2	1.23	1.55	1.86	1.63	2.06	1.75	1.56	1.09
50%	3.61	1.87	2.1	2.28	1.25	1.94	1.6	2.12	2.28	2.69	2.27	2.12	1.53
75%	3.69	1.98	2.37	2.38	1.58	2.34	2	2.55	2.24	2.84	2.78	2.56	2.04
100%	5.32	2.83	2.58	2.52	1.92	2.53	2.98	2.64	2.82	3.21	3.45	3.12	2.47

Carbon dioxide variation with brake power for diesel and biodiesel blends is presented in Figure 5.6. Generally diesel engine producing higher amount of carbon dioxide emission at low loads and giving lower values at higher loads. At full load, CO₂ emission for B10, B20, B30, B10+NP1, B30+NP1, B10+NP2, B20+NP2, B30+NP2, B10+MNP, B20+MNP, and B30+MNP at maximum load is 2.83%, 2.58%, 2.52%, 1.92%, 2.53%, 2.98%, 2.64%, 2.82%, 3.21%, 3.45%, 3.12%, and 2.47% respectively, and for diesel it is 5.32% at full load.

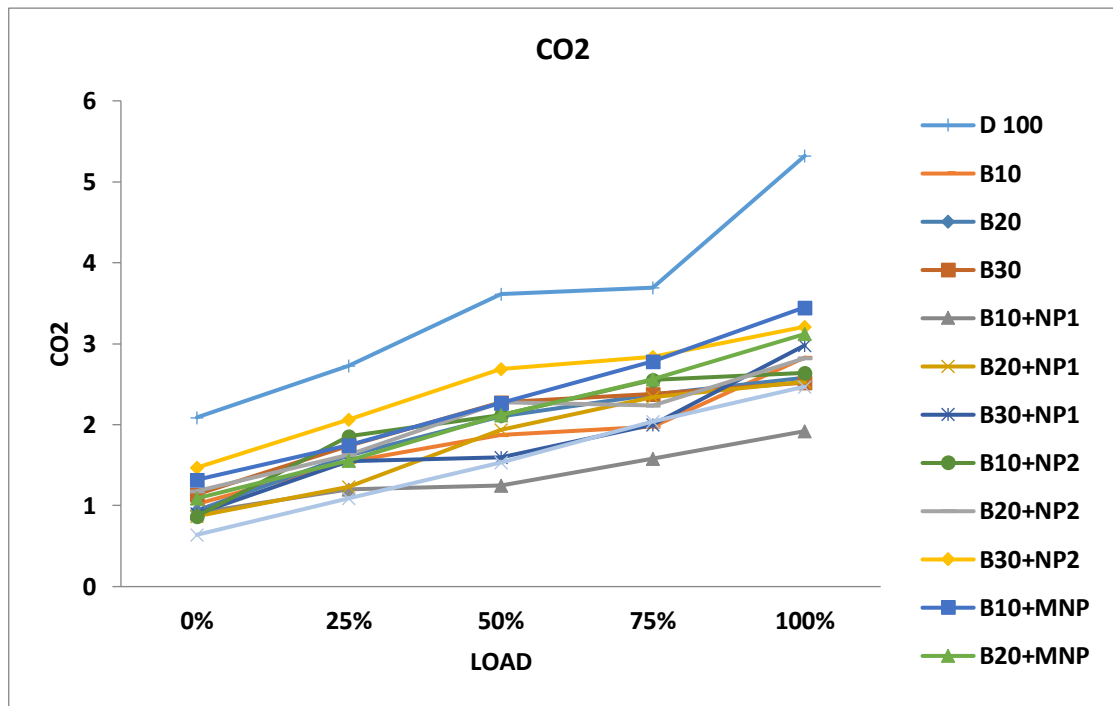


Figure5.6: Load Vs Carbon dioxide

CHAPTER VI

CONCLUSIONS

This study was an attempt to explore the possibilities of developing an alternative fuel source through Pithecellobium dulce Seed oil and diesel blends. Pithecellobium dulce Seed oil has been used as a flavoring agent but has never been researched in the field of biodiesel. It was also done in order to analyze the effect of nano additives like Cerium Oxide (CeO_2) and Nickel Oxide (NiO) on the blends of Pithecellobium dulce Seed oil and diesel. Fundamental parameters were considered in the experimental analysis. Brake thermal efficiency and specific fuel consumption came under the performance parameters whereas NO_x , CO, CO_2 and hydrocarbon emissions were taken as the emission characteristics. The emission results were positive with NO_x emissions at a depreciated value of 505 ppm from the sample (B10+NP1) at full load condition which is significantly lower than neat/pure diesel which emits 1151 ppm. The NO_x emissions were observed to be low under all the loads when compared to the pure diesel. This shows that the WJB30 biodiesel and diesel blend can be considered as an appropriate combination of biodiesel that can cut emissions of NO_x from a diesel engine. However, the CO and HC levels of the blends seemed to decrease drastically with respect to pure diesel. The readings obtained showed the emissions of B10+NP1 blend to be nearly twice the value of pure diesel under all load parameters. Hence, B10+NP1 sample can be considered useful in cutting off the NO_x emissions from the engine. Also, other biodiesel blend has shown appreciable results.

The performance parameter, brake thermal efficiency was maximum and even higher than neat diesel from the usage of B10+NP1 diesel blend. The readings observed were found to be close to the values of pure diesel under similar load conditions. than neat diesel.

Finally concluded that B10+NP1 with Cerium Oxide (CeO_2) nano particles at different loads in different diesel blends at 180 bar injection pressure. The B10+NP1 blends were found good results than Pure diesel. In the study to adding nano particles in biodiesel with diesel blends in engines shows that some changes in engine performance and emission values. it clearly shows that bio diesel of Pithecellobium dulce Seed oil biodiesel are source alternative for fossil fuels. the following optimum results were obtained for B10+NP1 biodiesel blend.

- ✓ Brake thermal efficiency of the engine in B10+NP1 is 8.32% more than diesel fuel.
- ✓ The BSFC all the values are similar to the diesel fuel.
- ✓ The HC ,CO,CO₂emissions reduced 8.3%, 8.4% and 12% than diesel.
- ✓ The NO_x level for B10+NP1 is 43% were reduced than diesel.

REFERENCES

- [1] Ganesh D, Gowrishankar G. Effect of nano-fuel additive on emission reduction in a biodiesel fuelled CI engine. IEEE 2011 International Conference on Electrical and Control Engineering (IECE); Yichang. (2011), pp. 3453–9.
- [2] Ghosh.S, Chaudhuri.S.N and Dutta.D, Nox reduction by using urea injection and marine ferromanganese nodule as scr of a diesel engine fulled with pongamia pinnata methyl ester, International Journal of Modern Engineering Research, Vol.3, Issue 2, (2013), pp.779-784.
- [3] Howard L. Fang*, Herbert F.M. and DaCosta, Urea thermolysis and NOx reduction with and without SCR catalysts, Applied Catalysis B: Environmental, Vol.46, (2003), pp.17-34.
- [4] Husnawan M, Masjuki H, Mahlia TM I, Mekhilef S,M.G Saifullah, “ Use of post flame metal-based andoxygenated additive combination for biodiesel-dieselblends,” Journal of Scientific & Industrial Research,vol. 68, (2009), pp. 1049-1052.
- [5] Jiranart Jeenchay and Kitipat Siemanond, Ammonia/Urea Production Process Simulation/Optimization with Techno-Economic Analysis, Proceedings of the 28th European Symposium on Computer Aided Process Engineering, <https://doi.org/10.1016/B978-0-444-64235-6.50070-X>.
- [6] Julia M.C.S. Magalhaes.S , Adelio and Machado.A.S.C , Urea potentiometric biosensor based on urease immobilized on chitosan membranes, Talanta, Vol.47, (1998), pp.183-191.
- [7] Karthickeyan Viswanathan, Experimental investigation on emission reduction in neem oil biodiesel using selective catalytic reduction and catalytic converter techniques, Environmental Science and Pollution Research, <https://doi.org/10.1007/s11356-018-1599-9>.
- [8] Kasim Mohammed Hello AbdulKarim-Talaq Mohammad and Athra Gutamy Sager, Solid Urea Sulfate Catalyst for Hydrolysis of Cellulose, Waste Biomass Valor, DOI 10.1007/s12649-016-9693-z.
- [9]Mohammad khristamto, and jo hyun, A study of urea injection timing to predict NOx conversion in SCR systems, Energy procedia, Vol.158, (2019), pp.1942-1948.

- [10] Pradipkumar B, Sanjib Pohit, Rajesh Kumar, "Biodiesel from Jatropha: can India meet the 20% blending target?," *Energy Policy*, vol. 38, (2010), pp.1477-1484.
- [11] Qian Wang, Fangyin Tu, Jun Ma, Hang Xu, Pin Qi, and Xiaojing Han, Urea-SCR Catalyst Research and Exhaust Pipe Layout Optimization, *IEEE*, 978-1-4244-8039-5/11 (2011).
- [12] Rafal Sala , Piotr Bielaczyc and Marek Brzezanski , Concept of Vaporized Urea Dosing in Selective Catalytic Reduction, *Catalysts*, Vol.7, (2017),pp.1-10.
- [13] Remiszewska.E, Malecha, J. Kruk. Jankowska and D.G. Pijanowska.D.G, Enzymatic method of urea determination in LTCC microfluidic system based on absorption photometry, Sensor and actuator, DOI: <https://doi.org/10.1016/j.snb.2019.01.032>
- [14] Thiyagrajan.S, .Herfat Manesh.M.R, Edwin Geo.V, and Peng.Z, "Experimental investigation in to the effect of magnetic fuel reforming on diesel combustion and emissions running on wheat germ and pine oil", *Fuel Processing Technology*, vol. 186, (2019), pp 116-124.