

ANALYSIS OF BIO-CATALYST IN CI ENGINE WITH HYDROGEN AS FUEL

Submitted in partial fulfilment of the requirements for the award of

**Bachelor of Engineering Degree in
Mechanical Engineering**

By

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**DEPARTMENT OF MECHANICAL ENGINEERING SCHOOL OF
MECHANICAL ENGINEERING**

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited with Grade "A" by NAAC

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **CYRIL PRAVEENRAJ J (38150014)** who carried out the project entitled "**ANALYSIS OF BIO CATALYST IN CI ENGINE WITH HYDROGEN AS FUEL**" under my supervision from

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I **CYRIL PRAVEENRAJ J** hereby declare that the Project Report entitled **“ANALYSIS OF BIO-CATALYST IN CI ENGINE WITH HYDROGEN AS FUEL”** done by me under the guidance of **Dr J. HEMANANDH, M.E., Ph.D.** and at **SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY, CHENNAI** is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in Mechanical Engineering.

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ABSTRACT

The ongoing fight against climate change has launched a global initiative to discover an appropriate alternative to existing fuel sources. Biodiesel is one such solution that is environmentally friendly and can be easily made from waste resources. Non-edible oil, *Jatropha Curcas* Oil was used in the synthesis of biodiesel. A solid based heterogeneous catalyst, Calcium oxide, was derived from Eggshell and calcinated at around 800° C for 2 hours. Tests such as SEM EDAX were done and elemental compositions were found. Transesterification was carried out at 60 °C in a 1:13 ratio of oil to methanol. The amount of catalyst used for transesterification was 3.5 % wt. of the oil. The B10 and B20 fuel blends were enriched with hydrogen at 3 LPM and 9 LPM. Various tests on parameters of fuel such as Emission, Combustion and Performance were done and compared with Pure Diesel.

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LIST OF ABBREVIATION

ACRONYM	EXPANSION
CI	Compressed Ignition.
JCO	<i>Jatropha curcas</i>
LPM	Litre per minute
CO	Carbon monoxide.
HC	Hydrocarbon.
CO ₂	Carbon dioxide.
NO _x	Nitrogen Oxides.
O ₂	Oxygen.
UBHC	Unburnt Hydrocarbon
BTE	Brake Thermal Efficiency.
BP	Brake power.
BSFC	Brake Specific fuel consumption.
D.I	Direct Injection.
HRR	Heat release rate
RPM	Rotations per minute.
B10	10 % Biodiesel 90 % Diesel
B20	20 % Biodiesel 80 % Diesel
LPG	Liquified Petroleum Gas
FAME	Fatty Acid Methyl Ester
FFA	Free Fatty Acid
CNG	Compressed Natural Gas
H ₂	Hydrogen
CaO	Calcium Oxide
CaCO ₃	Calcium Carbonate
KOH	Potassium Oxide
NaOCH ₃	Sodium Methoxide
NaOH	Sodium Oxide
ASTM	AMERICAN SOCIETY OF TEST AND MATERIALS
LPG	Liquefied petroleum gas
EGR	Exhaust Gas Recirculation

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CHAPTER – 1

INTRODUCTION

1.1 ALTERNATIVE FUELS

Alternative fuels are derived from sources aside from fossil oil. More than a dozen alternative fuels are being synthesized or developed for use in conventional vehicles and advanced technology vehicles. Most of these fuels are used primarily by government and private-sector vehicle fleets. However, nowadays individual consumers are becoming more interested in green fuels. Using alternative fuels and modern vehicles instead of conventional fuels and automobiles helps the Indian government to save fuel and reduce vehicle emissions.

1.1.1 Ethanol

Ethanol is a sustainable, domestically manufactured alcohol fuel derived from plants such as maize, sugar cane, or grasses. Ethanol use can help to reduce fossil fuel consumption and greenhouse gas emissions.

1.1.2 Electricity

Electricity is a fuel equivalent that can be used to power all-electric and plug-in hybrid vehicles. Using electricity to power vehicles can be cost-effective and offer major energy security and emissions benefits. Electricity is often less expensive to fuel than gasoline or diesel. Automobiles, however, are often more expensive than their gasoline counterparts.

1.1.3 Natural Gas

Natural gas is one of the most environmentally beneficial alternative fuels because it is mostly made up of methane. In the form of compressed natural gas or liquefied natural gas, it can be used to power cars, autorickshaws, and trucks. Natural gas is most often extracted from gas and oil wells. Hydraulic fracturing is what it's called. Natural gas is mostly used in residential homes, commercial office buildings, industrial applications, and the generation of electricity. Only a tenth of one per cent of

natural gas is now used for transportation. Dedicated natural gas vehicles are designed to run exclusively on natural gas, whereas bi-fuel vehicles can also run on gasoline or diesel. When natural gas is available, bi-fuel vehicles allow customers to take advantage of the ubiquitous supply of gasoline or diesel while also using a cleaner, more cost-effective alternative. On a big scale, natural gas automobiles are not available. Conventional gasoline and diesel vehicles, on the other hand, can be converted to run on CNG.

1.1.4 Biodiesel

Biodiesel is a type of diesel fuel that is manufactured from vegetable oils, animal fats, or recycled restaurant oils. It is non-hazardous, biodegradable, and emits lesser pollutants into the atmosphere than petroleum-based diesel. Biodiesel can be used either in its pure form (B100) or combination with petroleum diesel. Blends that are commonly used include B2 (2 percent biodiesel), B5, and B20. However, many manufacturers will accept blends up to B5. Some permit mixtures of up to B20.

1.1.5 Propane

Liquefied petroleum gas (LPG), often known as propane Autogas, is a clean-burning alternative fuel that has been used to power light, medium, and heavy-duty propane vehicles for decades. Propane is an alkane gas with three carbon atoms (C_3H_8). It is kept as a colourless, odourless liquid under pressure in a tank. When the pressure is released, the liquid propane vaporizes and transforms into a gas that can be burned. For leak detection, ethyl mercaptan is used as an odorant. Propane has a high-octane rating, making it a good choice for internal combustion engines that use spark ignition. It poses no hazard to the soil, surface water, or groundwater if spilt or released from a vehicle. Propane is created as a by-product of the natural gas and crude oil refining processes. It accounts for around 2% of total energy consumption in the United States. Only about 3% of that is used for transportation. Its primary applications include house and water heating, food preparation and refrigeration, clothing drying, and farm

and industrial equipment powering. Propane is also used as a raw ingredient in the chemical industry to make polymers and other chemicals.

1.1.6 Hydrogen

The Energy Policy Agreement of 1992 classifies hydrogen as an alternative fuel. The ability to operate fuel cells in zero-emission vehicles, as well as the fuel cell's rapid filling time and high efficiency, have garnered attention in hydrogen as an alternative transportation fuel. A fuel cell with an electric motor is two to three times more efficient than a gasoline-powered internal combustion engine. Internal combustion engines can use hydrogen as a fuel.

1.2 BIOFUELS

Energy obtained from biofuels is referred to as bioenergy. Biofuels are fuels created explicitly or implicitly from organic matter, such as biomass, plant materials, and animal waste. Bioenergy currently meets about 100 percent of global energy needs. Fuelwood, charcoal, and animal dung are instances of older unprocessed biomass.

Many of these are accounted for, and it is the most abundant source of energy for a large number of people in underdeveloped nations who use it mostly for food preparation and heating. Biofuels may now be extracted from materials such as wood, crops, and garbage using more advanced and cost-effective conversion technology. Even though the phrase is widely used in the literature in a very narrow sense to refer primarily to liquid biofuels for locomotion, biofuels will be solid, gaseous, or liquid. Crops, as well as ordinary food plants and specific energy crops, could be used to make biofuels. Biofuels can be made from biological, agricultural or forestry wastes, or municipal wastes, as well as by-products and wastes from the food industry and foodservice. There is a differentiation between primary and secondary biofuels. Organic resources are used in an unprocessed form in primary biofuels like fuelwood, wood chips, and pellets, principally for heating, cooking, and electricity production. Secondary biofuels are liquid biofuels such as fermentation alcohol and biodiesel that can be used in automobiles and industrial activities as a result of biomass processing.

Bioenergy is primarily used in residences (80%), with a smaller percentage used in businesses (18%), while liquid biofuels for transportation still play a minor role (2 per cent). Even though the assembly of liquid biofuels for transport has big speedily in recent years it presently represents only one of total transport fuel consumption and solely 0.2 to 0.3% of total energy consumption worldwide.

1.2.1 Biodiesel

Biodiesel is a clean-burning alternative fuel made from domestically available renewable resources. This biofuel could be built up of carboxylic acid alkyl radical esters derived from vegetable oils, animal fats, or recycled grease. Biodiesel is used in compression-ignition engines in its purest form with little or no modifications.

Generally, there are two types of oil for the production of biodiesel

A) Edible Oil:

These types of oils are generally used directly for human consumption. They are also called cooking oil. The term 'vegetable oil' is used to refer to a blend of oil that is used for cooking purposes. Ex: Soybean Oil, Sunflower, Olive, etc.

B) Non-Edible Oil:

These types of oils are generally used in industries as fuels and biofuels, thus have been selected for our project for similar purposes. They cannot be consumed, as their name suggests. Ex: JCO, castor oil, karanj oil, Neem oil

Biodiesel comes in a variety of concentrations and can be combined. B5 (up to 5% biodiesel) and B20 (up to 20% biodiesel) are the most frequent (6 percent to 20 percent biodiesel). B100 (pure biodiesel) is most commonly used as a blendstock for lower blends and is rarely utilized as a transportation fuel. B20 is a desirable blend because it offers an excellent balance of price, emissions, cold-weather performance, materials compatibility, and solvent capabilities. The majority of biodiesel users buy B20 or lesser blends from their regular gasoline distributors or biodiesel marketers. Engines that run on B20 consume the same

amount of fuel, produce the same amount of horsepower, and produce the same amount of torque as engines that run on petroleum diesel. Although B20 with 20% biodiesel content has 1% to 2% less energy per gallon than petroleum diesel, many B20 users say there is no discernible difference in performance or fuel economy. Biodiesel has some pollution advantages, particularly for engines built before 2010. Biodiesel, on the other hand, emits fewer greenhouse gases than traditional diesel fuel. The emissions reduction advantage is roughly proportional to the blend level; for example, B20 has 20% of the emissions reduction benefit of B100.

However, Due to a lack of regulatory incentives and pricing, B100 and other high-level biodiesel blends are less often employed as a transportation fuel over B20 and lower blends. Certain parts, including hoses and gaskets, are biodiesel-compatible, allowing B100 to be utilized in engines made after 1994. B100 has a solvent action, which allows it to clean a vehicle's fuel system and remove deposits developed through the use of petroleum diesel. In the first few tanks of high-level blends, the discharge of these deposits may block filters and necessitate frequent filter replacement. B100 and other high-level biodiesel blends are less commonly used directly as a transportation fuel than B20 and lower blends due to a lack of regulatory incentives and pricing. Biodiesel-compatible material for certain parts, such as hoses and gaskets, allow B100 to be used in some engines built since 1994. B100 has a solvent effect; it can clean a vehicle's fuel system and release deposits accumulated from petroleum diesel use. The release of these deposits may initially clog filters and require frequent filter replacement in the first few tanks of high-level blends

When using high-level blends, several factors should be considered. Pure biodiesel contains less energy on a volumetric basis than petroleum diesel. Therefore, the higher the percentage of biodiesel (above 20%), the lower the energy content per gallon. High-level biodiesel blends can also impact engine warranties, gel in cold temperatures, and may present unique storage issues. B100 use could also increase nitrogen oxide emissions, although it greatly reduces other toxic emissions. B100 requires special handling and may require equipment modifications.

1.2.2 JCO as a Feedstock

Energy crops are crops that are grown specifically for the generation of fuel and energy. Currently, these crops constitute a negligible portion of the overall biomass energy produced each year. This number, however, is likely to rise over the following few decades. Energy crops, however, compete for land designated for food production, environmental protection, forestry, or nature conservation. High yield (highest dry matter per hectare production), cheap cost, low energy input, low nutrient or fertilizer requirements, pest resistance, and the composition with the fewest pollutants generated are all features of optimal energy crops.

Because of its quantity and productivity, palm oil is regarded as India's most valuable energy crop. However, rather than being viewed as a fuel source, this crop is still viewed as a key source of vegetable oil around the world, and demand for that as an ingredient is growing. As a result, using inedible food crops like *Jatropha curcas* as a biodiesel feedstock could help solve some of the major concerns that plagued the first iteration of biodiesel feedstock, such as the food vs. fuel conundrum, scaling issues, as well as the inability to grow on remote land, among many others. This has a longer average productive life than oil palms. The plant is a drought-resistant evergreen that thrives in the marginal territory with poor soil and other negative features that make it inappropriate for agribusiness or commerce. As a result, unlike some of the other common edible feedstocks, the cultivation of this crop causes no harm to exist arable land or the food chain. Since it is biodegradable, non-toxic, and environmentally benign with fewer greenhouse gas emissions, biodiesel fuel has been widely embraced in most nations. Furthermore, using biodiesel is thought to be a good way to reduce noise and perhaps reduce air pollutants such as carbon monoxide (CO), Sulphur, polycyclic aromatic hydrocarbon, smoke, and particle matter. Density, viscosity, cetane number, and flash point are the most important fuel parameters to consider while using biodiesel in diesel engines. The Cetane number is the most important measure of fuel quality, especially for diesel engines' ignition and combustion. A high Cetane number typically suggests a shorter ignition delay time—that is, the time between injecting the fuel and initiating ignition in the combustion chamber. The parameter is typically used to ensure good fuel

combustion, cold start, and performance characteristics, as well as reduced white smoke generation and emissions. The cetane number of Jatropha is said to be as high as 55, which is identical to diesel. Biodiesel must reach the minimum flashpoint, which is over 120 degrees Celsius, according to both specifications. The temperature at which a fuel commences to burn after colliding with fire is known as the flashpoint. Any fuel with a high flash point could typically result in carbon deposition in the combustion compartment. Since Jatropha oil has a lower flash point than palm oil (162°C Vs. 181°C, respectively), it has a bigger potential as biodiesel than palm oil.

1.3 CATALYST

A catalyst is a substance that either accelerates nor reduces the temperature or pressure required to initiate a chemical reaction, either with being consumed during the reaction. In transesterification process a role for a catalyst is to speed up the conversion, and a surplus of alcohol is necessary to shift the equilibrium toward the synthesis of fatty acid alkyl esters and glycerol. Catalyst are classification into three types as seen in figure 1.1

1.3.1 Homogenous Catalyst

Homogeneous catalysts are catalytic chemicals that exist in the same phase as the components entering the reaction phase. These homogeneous catalysts are frequently liquid. Because the catalyst is in the same phase as the reaction mixture, recovering homogeneous catalysts is more difficult and expensive. This indicates that the catalyst separation is problematic. Homogeneous catalysts have poor heat stability as well. Homogeneous catalysts are very active at low temperatures (less than 250°C). When compared to heterogeneous catalysts, the catalytic activity of these catalysts is moderate. The selectivity, on the other hand, is high. Because catalytic recovery is difficult, recycling homogeneous catalyst is costly. However, because the catalyst is in the liquid phase, it is simple to modify. The homogeneous catalysts utilized for the transesterification reaction are classified into two groups, such as

- (i) base catalysts (for example, NaOH and KOH), and
- (ii) acid catalysts, such as sulphuric, sulphononic, hydrofluoric, and acids.

1.3.2 Heterogeneous Catalyst

Heterogeneous catalysts are catalytic substances that exist in a distinct phase than the reaction mixture. These catalysts can be found in all three phases of matter: solid, liquid, and gas. Catalytic recovery is simple and inexpensive with heterogeneous catalysts because the catalyst is in a separate phase from the reaction mixture. Metals, metal oxides, and other heterogeneous catalysts are common examples.

When compared to homogeneous catalysts, heterogeneous catalysts have superior thermal stability. These catalysts work effectively at high temperatures, ranging from 250 to 500 degrees Celsius. When compared to homogeneous catalysts, the catalytic activity is also high. However, reactant selectivity is lower than that of homogeneous catalysts. The active locations of heterogeneous catalysts remain unclear. This decreases selectivity.

1.3.3 Base Catalyst

Homogeneous base catalysts are most widely investigated in the transesterification of vegetable oil to FAME, as they are cheap and easily accessible. To date, several homogeneous base catalysts have been utilized for the synthesis of FAME, e.g., KOH, NaOH, and NaOCH₃. The use of CaO and KOH as catalysts resulted in outstanding catalytic activity for biodiesel generation, including a short reaction time and a high biodiesel output, and all of this happened at room temperature and pressure. However, there are certain drawbacks to this method, such as the formation of water as a byproduct, which reduces biodiesel production. However, it is fit for refined vegetable oils with low FFA content (ranging from less than 0.5 wt.% to less than 2 wt.%).

1.3.4 Acid Catalyst

Because they are more reactive and less expensive, base catalysts are frequently favoured over acid catalysts. Base catalysts, on the other hand, may react with the FFA in the feedstock during transesterification, resulting in soap formation via saponification, which consumes the catalyst and reduces its reactivity. Meanwhile, an acidic catalyst is neutral to FFA and hence produces better results when transesterifying or esterifying vegetable oils or fats with a high FFA content

(>2%). It has issues with the atmosphere and corrosion. Acid- catalyzed biodiesel synthesis is not particularly popular and is investigated less because of these drawbacks.

1.4 BIO - MASS CATALYST

The bio-waste produced heterogeneous catalyst has received substantial attention in recent years, both in the realms of catalysis and biofuel research, and has recently been reviewed by multiple writers. The benefits of using waste materials as a catalyst are mostly owing to its low cost, abundance, non-toxicity, Eco-friendliness, economics, renewable, sustainability, and ease of access. Many studies have used waste biomass as a catalyst for both low FFA oil (edible oil) and high FFA oil (edible and non-edible oils). Plant ashes, discarded shells, bones, and industrial wastes are among the biomass. Catalysts obtained from waste biomass have the potential to make biodiesel production both cost-effective and environmentally friendly.

1.4.1 Waste Eggshell

Although several of the previously listed chemically manufactured heterogeneous catalysts exhibit potential and fairly high biodiesel yields, their synthesis techniques can be difficult, expensive, chemically wasteful, time demanding, and non-economical. As a result, with the increasing need for renewable energy, there is a need to find an ideal heterogeneous catalyst that is simple to synthesize, non-toxic, low in cost, widely available, biodegradable and eco-friendly, and demonstrates high catalytic activity in biodiesel production. In light of this, the use of CaO (produced from the high-temperature calcination of waste shells containing CaCO_3) has recently been a front-runner. The use of waste shells as a source of CaO not only makes biodiesel production more sustainable but also solves the problem of waste disposal of massive amounts of waste shells generated by human consumption.

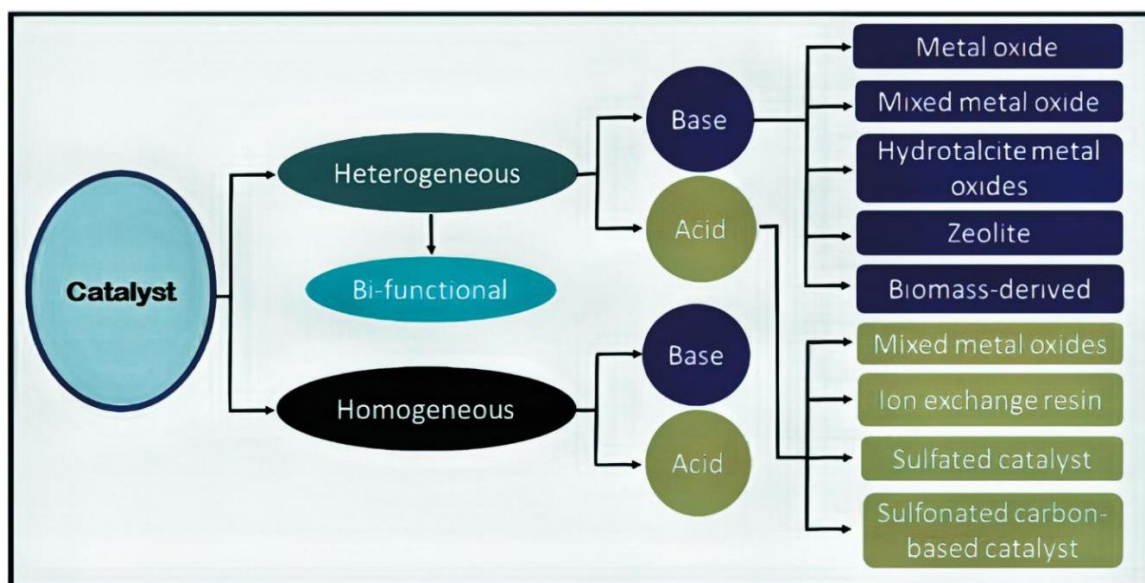


Fig 1.1: Classification of Catalyst

1.5 ADVANTAGES OF BIODIESEL

- Produced from Renewable Resources.
- Can be Used in Existing Diesel Engines.
- Less Greenhouse Gas Emissions (e.g., B20 reduces CO₂ by 15%).
- Grown, Produced and Distributed Locally.
- Cleaner Biofuel Refineries.
- Biodegradable and Non-Toxic.
- Better Fuel Economy.
- Reduced Foreign Oil Dependence.
- Improved Air Quality.
- Biodiesel is Undoubtedly a Safer Alternative to Fossil Fuels.
- Biodiesel Could Possibly End Energy Crisis and Energy Politics.

1.5.1 Disadvantages Of Biodiesel

- Variation in Quality of Biodiesel.
- Not Suitable for Use in Low Temperatures.
- Biodiesel Could Harm the Rubber Houses of Some Engines.
- Biodiesel is Way More Expensive than Petroleum.
- Use of Petroleum Diesel to Produce Biodiesel.

- Monoculture refers to the practice of producing the same crop over and over again rather than producing different crops.
- Clogging in Engine.
- Increased use of Fertilizers.
- Regional Suitability.

1.5.2 Applications

- In the Automobile industry
- In Aviation.
- In cooking.
- Energy Generations.
- Clean oil Spills and Grease.

1.6 HYDROGEN ENGINES

Reverend W. Cecil described the first effort at creating a hydrogen engine in 1820. In a paper titled "On the Application of Hydrogen Gas to Produce Moving Power in Machinery," Cecil presented his findings to the Cambridge Philosophical Society. The vacuum concept, in which atmospheric pressure forces a piston back against a vacuum to generate power, was used in the engine. The vacuum is formed by burning a hydrogen-air mixture and then letting it expand and cool. Despite the fact that the engine functioned properly, vacuum engines were never commercially viable. N. A. Otto (the developer of the Otto cycle) reportedly employed a synthetic production gas for fuel during his experiments with combustion engines Key Points & Notes in the 1860s and 1870s, which had a hydrogen content of over 50%. Otto also tried gasoline, but found it too risky to deal with, so he went back to using gaseous fuels. The carburetor, on the other hand, ushered in a new era in which gasoline could be utilized both practically and safely, and interest in alternative fuels waned. Since hydrogen has the best energy-to-weight ratio of any fuel, it has been employed extensively in the space program. Liquid hydrogen is the preferred rocket fuel, and it has been used in the upper stages of launch vehicles on numerous space missions, including the Apollo moon missions, Skylab, the Viking Mars probes, and the Voyager Saturn mission. In recent years,

Concerns about clean air, stronger air pollution regulations, and a desire to minimize reliance on fossil fuels have reignited interest in hydrogen as a vehicle fuel in recent years.

Hydrogen can be used advantageously in internal combustion engines as an additive to hydrocarbon fuel. Hydrogen is most commonly mixed with high-pressure natural gas for this purpose since both gases can be stored in the same tank. If hydrogen is blended with other fuels, it usually has to be stored separately and mixed in the gaseous state immediately before ignition. In general, it is impractical to use hydrogen in conjunction with other fuels that also require bulky storage systems, such as propane. Gaseous hydrogen cannot be stored in the same vessel as a liquid fuel. Hydrogen's low density will cause it to remain on top of the liquid and not mix. Furthermore, liquid fuels are stored at relatively low pressures so that very little hydrogen could be added to the vessel. Liquid hydrogen cannot be stored in the same vessel as other fuels. Hydrogen's low boiling point will freeze other fuels resulting in fuel "ice"! Hydrogen can be used in conjunction with compact liquid fuels such as gasoline, alcohol or diesel provided each is stored separately. In these applications, the fuel tanks can be formed to fit into unused spaces on the vehicle. Existing vehicles of this type tend to operate using one fuel or the other but not both at the same time. One advantage of this strategy is that the vehicle can continue to operate if hydrogen is unavailable. Hydrogen cannot be used directly in a diesel (or "compression ignition") engine since hydrogen's autoignition temperature is too high (this is also true of natural gas). Thus, diesel engines must be outfitted with spark plugs or use a small amount of diesel fuel to ignite the gas (known as pilot ignition). Although pilot ignition techniques have been developed for use with natural gas, no one is currently doing this with hydrogen. One commercially available gas mixture known as Hythane contains 20% hydrogen and 80% natural gas. At this ratio, no modifications are required to a natural gas engine, and studies have shown that emissions are reduced by more than 20%. Mixtures of more than 20% hydrogen with natural gas can reduce emissions further but some engine modifications are required.

The lean operation of any internal combustion engine is dangerous in terms of oxides of nitrogen emissions and fuel economy. As with hydrogen, the drawback of lean operation with hydrocarbon fuels is reduced power output. The lean operation of hydrocarbon engines has additional drawbacks. Lean mixtures are hard to ignite, despite the mixture being above the LFL of the fuel. This results in a misfire, which increases unburned hydrocarbon emissions, reduces performance and wastes fuel. Another disadvantage is the reduced conversion efficiency of 3-way catalytic converters, resulting in more harmful emissions. To some extent, mixing hydrogen with other hydrocarbon fuels reduces all of these drawbacks. Hydrogen's low ignition energy limit and high burning speed make the hydrogen/hydrocarbon mixture easier to ignite, reducing misfire and thereby improving emissions, performance and fuel economy. Regarding power output, hydrogen augments the mixture's energy density at lean mixtures by increasing the hydrogen-to-carbon ratio and thereby improves torque at wide-open throttle conditions.

1.6.1 Combustive Properties of Hydrogen

The properties that contribute to its use as a combustible fuel are its:

- wide range of flammability
- low ignition energy
- small quenching distance
- high autoignition temperature
- high flame speed at stoichiometric ratios
- high diffusivity
- very low density

1.6.2 Fuel Delivery system with Hydrogen in CI Engines

Adapting or re-designing the fuel delivery system can be effective in reducing or eliminating pre-ignition. Hydrogen fuel delivery systems can be broken down into three main types: central injection, port injection and direct

injection. Central and port fuel delivery systems injection form the fuel-air mixture during the intake stroke. In the case of central injection or a carburettor, the injection is at the inlet of the air intake manifold. In the case of port injection, it is injected at the inlet port. Direct cylinder injection is more technologically sophisticated and involves forming the fuel-air mixture inside the combustion cylinder after the air intake valve has closed.

CHAPTER – 2

LITERATURE REVIEW

1. Achten, W.M.J., et al., (2008) stated that employing Jatro bio-diesel (i.e., methyl esters) or JCL oil is based on the intended usage and the infrastructure available. In unmodified diesel engines, studies demonstrate that trans esterified JCL oil performs better than pure JCL oil, straight or in a blend.
2. Aldhaidhawi M et al., (2017) study on hydrogen addition states that adding B20 with the aspiration of the intake airflow reduced CO emissions, smoke, and total unburned hydrocarbon emissions.
3. Bobade, S., R. Kumbhar, and V. Khyade, Preparation., (2012) work has stated that Pongamia pinnata oil usually has high acid content and these kinds of oil usually need esterification before transesterification.
4. Bobade, S., R. Kumbhar, and V. Khyade., (2013) in his Preparation of methyl ester (Biodiesel) from Jatropha curcas Linn oil observed that JCO needs to be esterified before transesterification since its acid content was high.
5. Boßelmann, F., et al., (2007) work observed Eggshell has abundant Calcium carbonate and can use a catalyst after calcination.
6. Brito, A., M. Borges, and N. Otero., (2007) stated that usage of heterogenous catalyst zeolite Y increases the corrosiveness of the end product.
7. Chavan, S., R. Kumbhar, and R. Deshmukh., (2013) study focuses on using non-edible oil like JCO, Pongamia pinnata, Manduca indica and successfully transesterifying them in the ratio of 1:8 oil to methanol and 1.5 wt% at 65 °C.

8. Chavan, S.B., Kumbhar, R.R. and Sharma, Y.C., (2014) in their work have stated that the transesterification process for waste oil or vegetable oil is easy to produce if the free fatty acid content is less than 4%.
9. Chavan, S.B., Kumbhar, R.R., Madhu, D., Singh, B. and Sharma, Y.C., 2015 has obtained high purity calcium oxide from eggshell at 900°C for ~2.5 h and transesterification was carried out using JCO as feedstock where high yield of biodiesel to 90% was obtained.
10. Goli, J. and Sahu, O., 2018 found that The maximum biodiesel yield of 93% and 92.32%; experimental and predicted respectively was obtained at a reaction temperature of 57.5 °C, the reaction time of 3 h, methanol to oil molar ratio of 10:1, catalyst concentration of 7 wt%. The experiment was carried out in the three-necked batch-glass reactor at atmospheric pressure.
11. Hariharan et al (2019) presented enrichment of hydrogen in 20 % and 30 % Blends and have concluded that a 20 % blend with hydrogen provides better performance and reduction in emission.
12. Hosseini S.M et al. (2017) measured 17%, 8%, 69%, and 9.5% lower CO, CO₂, unburned hydrocarbon, and soot emissions, respectively and 2% higher NO_x emissions with the addition of hydrogen as a fuel excess.
13. Hui Khim et al., (2021) has stated that both features, particularly the high basicity, density and strong basic strength of the catalyst, were found to significantly improve the transesterification process for biodiesel.
14. Joshi G et al., (2015) have stated that the greatest conversion for transesterification of Jatropha and Karanja oils was achieved using a 5% catalyst, a 65 °C temperature, and a 12:1 methanol/oil ratio. During all four cycles, the catalyst was successfully re-used.
15. Kanth, S et al. (2020) have investigated hydrogen enrichment with a neat diesel engine and have injected hydrogen in 13 LPM and the results were compared with the neat diesel.

16. Karagöz, Y., Güler, İ., Sandalcı, T., Yüksek, L. and Dalkılıç, A.S., (2016) has observed a decrease in CO emission and smoke emission with an increase of hydrogen enrichment and also there was a slight increase in THC emission.
17. Kirubakaran, M., 2018 in his work has obtained biodiesel from Chicken fat by using Eggshell as a catalyst for transesterification The optimum transesterification conditions are 1:13 M ratio, catalyst concentration of 8.5wt.% of oil, 5h reaction time, 57.5°C reaction temperature and fixed agitation speed of 500rpm; a yield of 92.5 % biodiesel was obtained
18. Kose and Ciniviz.,2013 observed the engine performance and the effect on emissions at 2.5%, 5% and 7.5% hydrogen volumes as a supplementary fuel at full load and for several engine cycles in a 4-stroke, water-cooled, 4-cylinder, direct injection diesel engine.
19. Liu, X., et al., (2004) in transesterification of Soybean oil and CaO as solid base catalyst experience difficulty in separation of Bio-diesel and glycerol.
20. Miyomato et al. (2011) studied a single-cylinder, common-rail fuel injection engine with EGR using a dual-mode injection of hydrogen via the manifold. They insisted on 2 methods to reduce the released NOx emissions: In the first method, low-temperature combustion, in other words, hydrogen, is added to the intake mixture and diesel fuel injection time is delayed in the second method, NOx and combustion noise are controlled with EGR and low hydrogen.
21. Mustafa Atakan Akar et al., (2017) stated that intake air was enriched with hydrogen rather than pure hydrogen, engine performance ratings improved in comparison to the usual diesel fuel operating condition in contrast, in terms of exhaust gas.
22. Mustafa Atakan Akar et al., (2018) stated that hydrogen enrichment improves brake thermal Efficiency and reduction in brake specific fuel consumption. Moreover, he reported that CO emissions reduced

- significantly and as well as a slight reduction in CO₂. However, NO_x emission has risen to 51.8 per cent when compared to pure diesel.
23. Openshaw., (2000) K., in his review of *Jatropha curcas*, an oil plant of unfulfilled promise, has stated that the by-product after transesterification can be used in making soaps
 24. Pan et al., (2014) did an experimental study on a two-stroke, marine diesel engine. The obtained results were compared with only diesel fuel, NO_x emissions decreased to 28% and 41%.
 25. Pandit, P.R. and Fulekar, M.H., 2017 have used chicken as a catalyst to synthesize calcium oxide nanocatalyst and obtained a yield of 86 per cent at a catalyst loading condition of 1.7% and a reaction time of 3.6 h
 26. Parthasarathy et al. (2016) asserted that the increment of NO_x can be diminished with biodiesel and ethanol blends by the injection of hydrogen into the fuel.
 27. Sandalcı, T. and Karagöz, Y., 2014 have investigated manifold injection using an LPG CNG injector and a decrement in pollutants was observed. However, NO_x remained constant.
 28. Shekar R.D et al., (2015) concluded that injecting hydrogen along with atmospheric air through the inlet manifold improves engine performance and combustion characteristics but has no effect on exhaust emission, fuel handling, and engine setup. It is suggested to use exhaust recirculation if there is an increased NO_x emission.
 29. Siow Hwa Teo et al., (2009) prepared nano-size heterogeneous catalyst from waste eggshell and achieved a yield of 97% at 300°C.
 30. Suppes, G.J., et al., (2004), in the transesterification of soybean oil with zeolite as a heterogeneous catalyst, observed an increase in the pH level of the biodiesel after transesterification.

31. Supriya et al., (2015) have stated that high purity calcium oxide was generated from eggshell and was employed as a catalyst for biodiesel generation, where it was calcined at 900 for 2.5 hours. The maximum yield for biodiesel 92 % was attained at a 1:8 temperature of 60 °C by stirring for 1.3 hours.
32. Suwannasom, P., Sriraksa, R., Tansupo, P. and Ruangviriyachai, C., 2016 have found the best values for the variables as MeOH/WCO ratio of 15.49:1 mol/mol, a catalyst weight of 6.42 wt per cent, and a reaction time of 128.67 min. Under ideal conditions, the percentage of FAME reached 97.59 per cent.
33. Tshizanga, N., Aransiola, E.F. and Oyekola, O., 2017. obtained a significant yield of 91% at optimal operating conditions of temperature 65 ± 5 °C, methanol to oil molar ratio 22.5:1 at a reaction time of 5 h 30 min, and catalyst loading 3.5 wt%. The catalyst showed sustained activity after being recycled and reused 10 times.
34. Tsujimura and Suzuki (2017) have injected hydrogen and have illustrated that using hydrogen instead of conventional diesel fuel caused a significant reduction of CO₂ emission and cylinder head temperature dependency on hydrogen fraction over 50%.
35. Uludamar. E et al. (2016) has investigated vibration in the engine through manifold injection. The study concluded that both biodiesel and hydrogen gas reduced engine vibration and exhaust emissions.
36. Viriya-Empikul, N., Krasae, P., Nualpaeng, W., Yoosuk, B. and Faungnawakij, K., 2012, concluded that waste materials were calcined in the air with optimum conditions temperature of 800 °C, time of 2–4 h and transformed calcium species in the shells into active CaO catalysts. All catalysts derived from egg and mollusc shells at 800 °C provided high activity >90% fatty acid methyl ester FAME in 2 h.

37. Wei, Z., Xu, C. and Li, B., 2009 have undertaken the transesterification process using Ostrich eggshell as a catalyst in oil to methanol ratio 1;14 in a time of 180 min and obtained a yield of 91 percentage
38. Zheng, M et al. (2008) has compared the diesel fuel engine-out emissions of nitrogen oxides (NO_x), a high-cetane number (CN) biodiesel fuel produced comparable to NO_x , while the biodiesel with a CN similar to the diesel fuel produced relatively higher NO_x at a fixed start of injection. The emissions of soot, carbon monoxide and un-burnt hydrocarbon were generally lower for the biodiesel-fuelled engine.

CHAPTER – 3

AIM AND SCOPE OF PRESENT INVESTIGATION

3.1 AIM

To study the emission and performance characteristics of biodiesel, prepared using eggshell as a catalyst and enriched with hydrogen in 3 LPM and 9 LPM.

3.2 SCOPE

The scope of this work is to:

- Use solid waste such as Eggshell as a Bio-catalyst to synthesize biodiesel
- Improve the performance of the engine with the addition of hydrogen in the combustion process.
- Reduce emissions such as HC, CO and CO₂ by injection of hydrogen.

CHAPTER – 4

MATERIALS AND METHODS

4.1 EGGSHELL

Eggshells were collected and rinsed with distilled water to avoid impurities during the process. It was then well washed in warm water at around 100°C to remove the inner membrane. It was dried in the sunlight and blended to a fine powder. The cleaned Eggshells were transferred to a muffled furnace where it was calcinated at 800 °C for two hours in presence of oxygen. The Calcination process is essential for the breakdown of the calcium carbonate to calcium oxide and carbon dioxide present in the eggshell. During the first 15 min of calcination, a pungent smell was observed and a slight smoke was released. After 1 hour, a colour change was observed from white to black. Upon further heating, the colour turned to ash. Further calcination at higher temperatures has shown an increase in CaO content [14,15]. A Pictorial illustration of the process is shown in Figure 4.1.

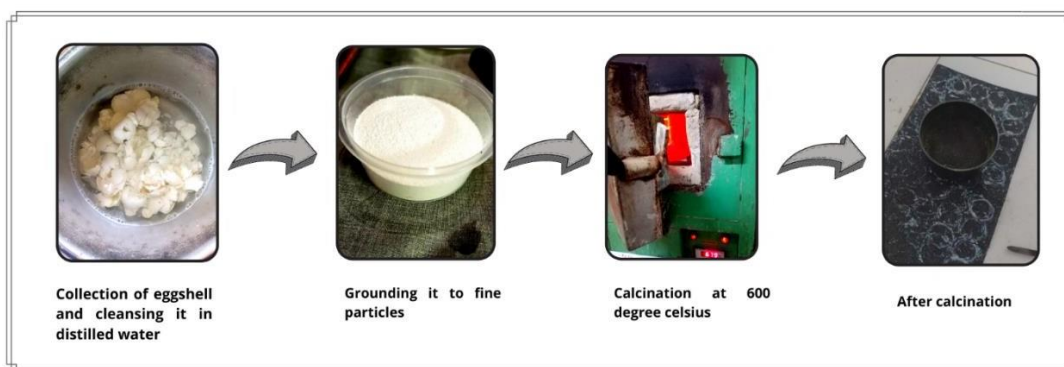


Fig. 4.1: Calcination of Eggshell

4.2 ANALYSIS OF CATALYST USING SEM – EDAX

A Scanning Electron Microscope (SEM) displays images at a magnification of 1000x resolution with a working distance of 30.00kV with a magnification of 2 µm. SEM provides detailed high resolution of the sample by passing a focused electron beam across the surface and detecting secondary or scatter electron signals. Through SEM EDAX one can identify the structural and elemental composition of the particle. SEM test was done to study the surface morphology of the calcinated

Eggshell. Its surface contains irregular shapes of particles such as Tod, dumbbells etc. as shown in Figures 4.2 and 4.3 and there is a large number of pores and cavities as observed. The particles got agglomerated which might have occurred due to the high calcination temperature. Additionally, there are irregularities in the morphology of metal impregnation catalyst as it is due to the formation of clusters. Figure 3 below depicts the area with the highest concentration of CaO, and when an electron microscope was focused on that specific area (Red), it was observed that Ca was 47.93 %, Oxygen was 37.51 %, and Carbon was roughly 14.56 %. Similarly, by altering, shifting, and focusing on another location as shown in figure 4 below, it was discovered that Ca was around 41.53 %, Oxygen was around 40.11 %, and the remaining 18.36% was carbon. Therefore, we can conclude that on average, 44.73 % of Ca and 38.81 % of oxygen were present. This proves that Egg Shell can be used as a potential catalyst for transesterification.

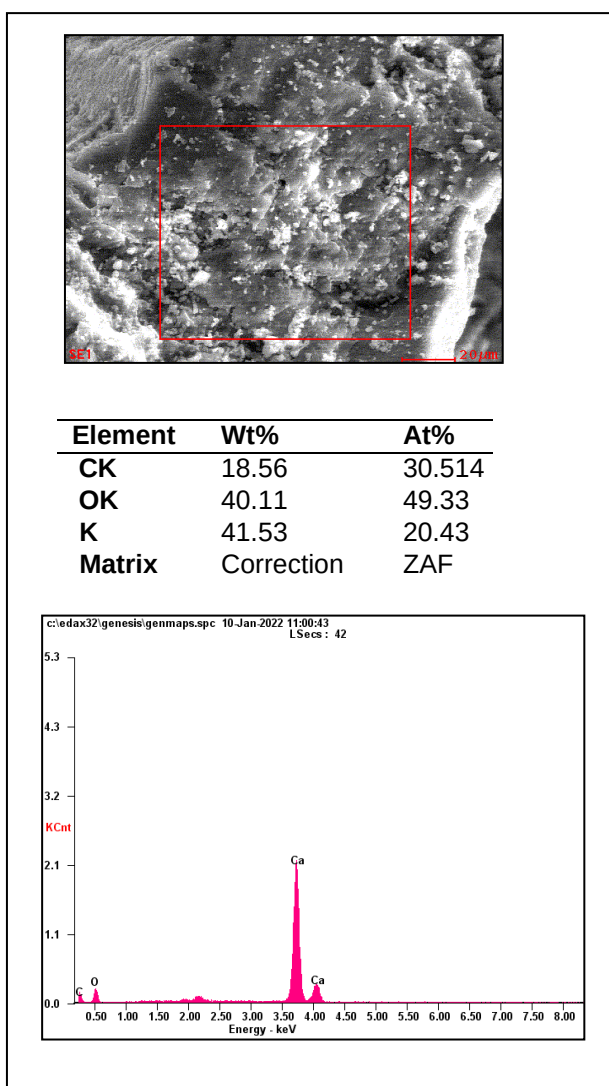


Fig. 4.2: SEM – EDAX at 20 μm

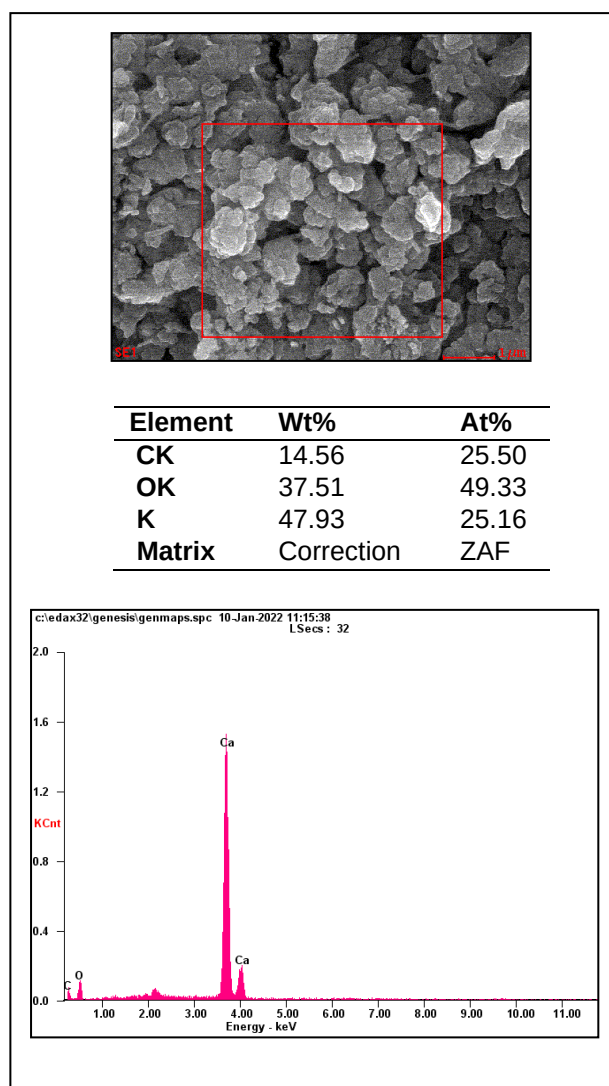


Fig. 4.3: SEM -EDAX at 1μm

4.3 FREE FATTY TEST FOR JATROPHA CURCAS OIL

A preliminary test FFA (Free Fatty Acid) test was done for the purchased JCO. It is to be noted that a high amount of FFA will result in soap formation upon reaction with catalyst and separation of the products will be extremely difficult. This test is done to determine whether either transesterification or esterification is supposed to be done for the given specimen. 5g of the sample is taken, after which 2.5 ml of isopropyl alcohol is added, after which 4 drops of 0.1 normality of NaOH are added. The sample is then heated for 60 degrees Celsius and subsequently cooled down to room temperature. 2 drops of an indicator called Phenolphthalein were added to titrate the solution against the normality of NaOH. As a result, the endpoint appears to be pink in colour. Then note the burette reading. Hence, the FFA of JCO was 1.23, which means $1.23 < 4$. Hence, transesterification was carried out. A graphical representation of the process is illustrated in Fig. 4.4

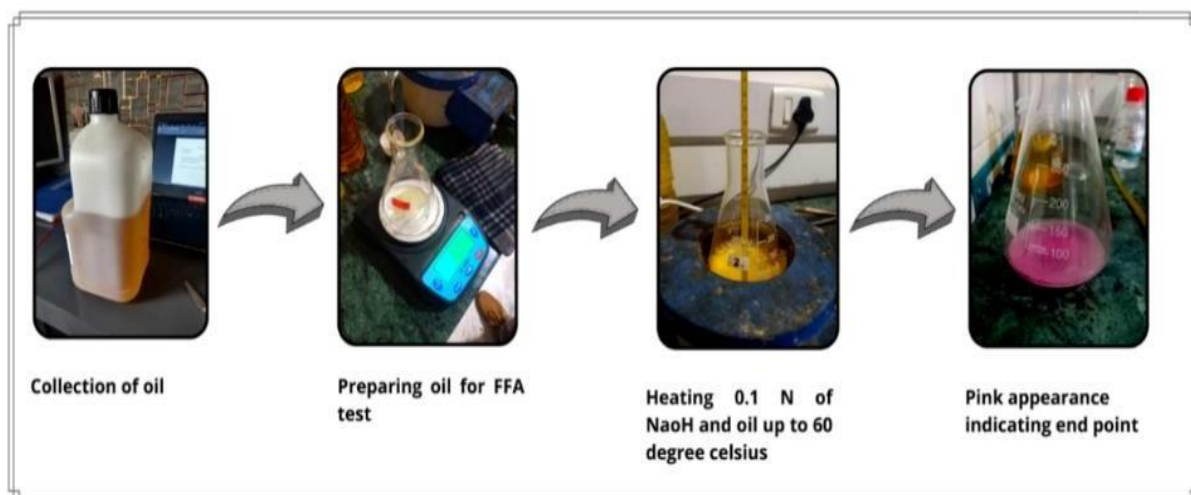


Fig.4.4: Free Fatty Acid Test

Table 4.1: Parameters of free fatty acid test

Sample(g)	Oleic acid(g)	NaOH	Burette Reading(ml)
5.06	2.82	0.1N	2.2

4.4 TRANSESTERIFICATION

It is the process where oil, which is a triglyceride, is converted to Fatty acid methyl ester (biodiesel) and glycerol by adding methanol in presence of a catalyst. The transesterification process was carried out in the International Research Centre at Sathyabama Institute of Science and Technology. Firstly, 800 ml of oil was taken and preheated up to 60 degrees Celsius and was allowed to cool down to room temperature. Then catalyst was measured and taken around 3.5 wt. of the oil. The oil was transferred to a 3- necked bottom flask and a reflux condenser were attached to one of its necks. A reflux condenser is attached to the flask to trap the excess methanol from being evaporated. The oil was transferred to a 3- necked bottom flask and a reflux condenser were attached to one of its necks. A reflux condenser is attached to the flask to trap the excess methanol from being evaporated. The oil was transferred into the flask and was kept stirred using a magnetic stirrer. Methanol was then measured as various authors suggested 1:13 was a feasible ratio and then it was mixed. After that, the catalyst was added and then the mixture was continuously stirred for up to 3 hours at 400 RPM. After 3 hours, the mixture was transferred to a separation funnel where a partial separation of the two layers was visible. As seen in fig.4.5, two distinct lines were visible after carrying out 3 wet washing processes. The wet washing process was carried out to remove excessive methanol content. The Total yield of biodiesel was about 93%.

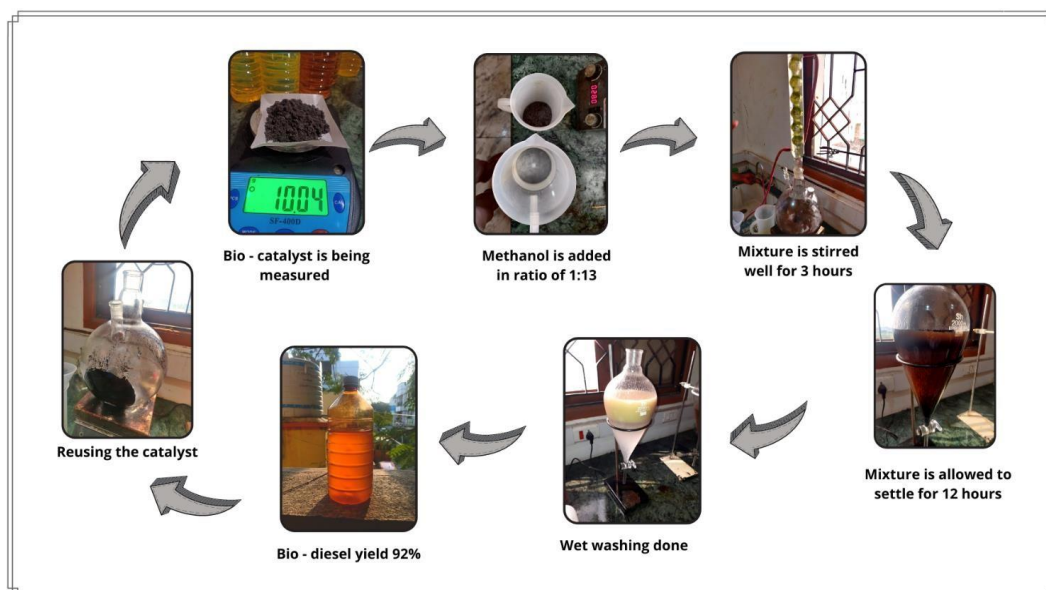


Fig. 4.5: Transesterification Process

Table 4.2: Properties of Hydrogen

Parameters	Value
Atomic mass	1.007825 g mol ⁻¹
Density	0.08375 kg/m ³
Boiling point	294 °C
Calorific Value	141000KJ/kg
Density	0.08375 Kg/m ³
Specific gravity	11.94 m ³ /kg

4.5 COMPARISON OF BIODIESEL Vs DIESEL AND HYDROGEN IN ASTM STANDARDS

Table 4.3: Fuel properties in accordance with ASTM standards

S. No	Parameters	Biodiesel	Pure diesel	ASTM Standards of pure diesel	Hydrogen
1	Density	880 Kg/m ³	830 Kg/m ³	820 -860 kg/m ³	0.0875 Kg /m ³
2	Kinematic Viscosity	1.28 mm ² /s	2.5 mm ² /s	1.9-4.1 mm ² /s	-
3	Flashpoint	61 °C	52 °C	52 °C	500 °C
4	Fire point	70 °C	60 °C	-	-
5	Calorific value	33000 kJ/Kg	42000kJ/Kg	42000 kJ/Kg	141.80 MJ/kg

Various fuel properties of Biodiesel, Pure Diesel, Hydrogen and ASTM standards of pure Diesel has been compared as shown in Table 4.3. In this table, the Density and the Calorific Value of Hydrogen, which has been derived from Table 4.2, the flash point of Hydrogen is fairly higher than that of Biodiesel, Pure Diesel and Pure Diesel in ASTM Standards. Meanwhile, Biodiesel has the lowest Kinematic Viscosity and higher Fire Point to that of Pure Diesel.

4.6 EXPERIMENTAL SETUP

The present investigation was carried out in a Kirloskar make a single-cylinder, water-cooled, four-stroke, direct injection (DI) diesel engine, developing a rated power of 5.2kW at a speed of 1500 rpm and having a compression ratio of 17.5:1. For loading the engine, an eddy current dynamometer was coupled to the engine. The gas was then metered out through a digital mass flow controller of Aalborg making for precision measurement of gas flow. The engine in-cylinder pressure was measured using a piezoelectric pressure transducer of air-cooled type with an inline charge amplifier. The amplified signals were correlated to the signal from the crank angle encoder having an accuracy of 1-degree crank angle. The data thus obtained were stored on a personal computer for analysis. The exhaust gas emissions such as carbon dioxide (CO₂),

carbon monoxide (CO), unburned hydrocarbon (UBHC), oxides of nitrogen (NO_x) and excess oxygen (O₂) available in the exhaust were measured by AVL gas analyzer. The resultant smoke was measured by AVL 437 smoke meter. Figure 4.6 represents the experimental setup.

4.7 SPECIFICATION OF ENGINE

Type	Four-stroke, Single Cylinder Vertical Water-Cooled Diesel Engine
Power	5.2 kW
Speed	1500 RPM
Bore Diameter	87.5
Stroke Length	110
Compression ratio	17.5 :1

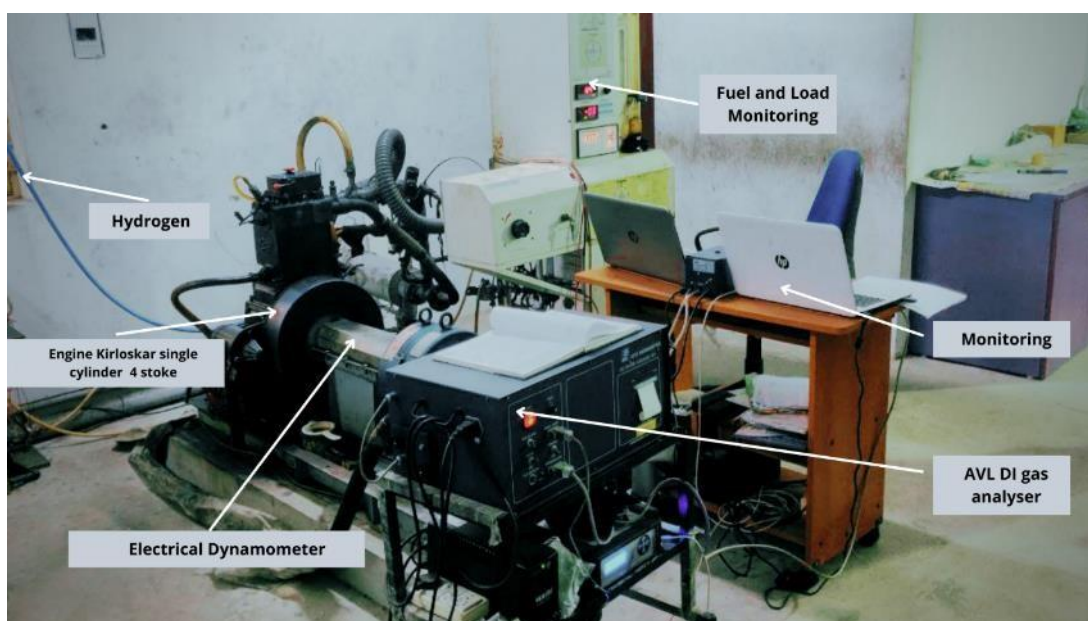


Fig. 4.6: Hydrogen Experimental Setup

4.8 ENRICHMENT OF HYDROGEN

Hydrogen can be added to a diesel engine in three methods one is direct injection, manifold injection, Continuous manifold injection. The manifold injection is where hydrogen is supplied in the manifold of the air intake and the air is replaced by hydrogen. Whereas in the case of direct injection, hydrogen is supplied directly to the

cylinder head however modification of the engine is required to ensure durability against high combustion temperatures. Figure 4.7,4.8 represents the manifold injection of hydrogen [35].

It is possible to use hydrogen in a dual fuel mode in a CI engine. In this mode, ignition can be realized by diesel pulverization because hydrogen is the main fuel, and it is known as the most practical method when combustion stability is considered. Thus, timing manifold/port injection, direct hydrogen injection and continuous manifold injection methods are applied. During the continuous manifold injection method, because of abnormal combustion, such as knock, pre-ignition and backfire, the engine working area is limited. During both timing manifold/port injection and continuous manifold direct injection methods, because a part of intake air is replaced by hydrogen due to drop of volumetric efficiency, a decrease in engine power is observed. These difficulties can be managed by direct hydrogen injection. However, a modification of the diesel engine and the addition of a high pressure H₂ injector on the cylinder head is required in this case. This high pressure H₂ injector cannot be easily found, so it should be manufactured with respect to a specific design that ensures durability against high combustion temperatures. As a result, the timing manifold/port injection method enables the use of hydrogen in diesel engines in the dual fuel mode with diesel pulverization. When compared to diesel fuel, hydrogen has a wider flammability limit, higher flame speed and faster combustion velocity. Moreover, hydrogen has a short quenching distance, high thermal value and high diffusivity. Hence, the use of hydrogen in diesel engines via the dual fuel mode by diesel pulverization is advantageous because PM emissions are reduced.

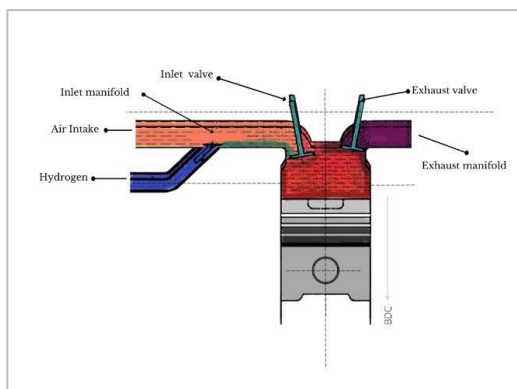


Fig. 4.7: Manifold Injection Illustration

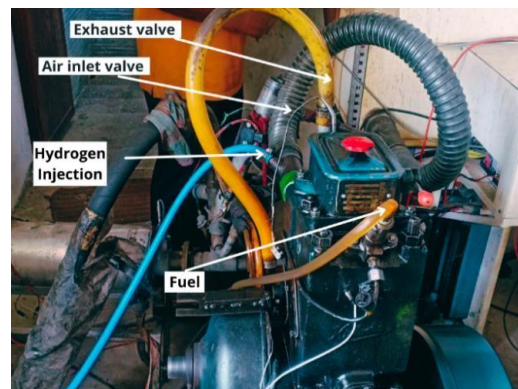


Fig. 4.8: Manifold Injection Actual Setup

CHAPTER 5

RESULTS AND DISCUSSION

5.1 EMISSION OF CARBON MONOXIDE(CO)

The above figures 5.1 illustrate the emission results. The charts compare between B10 9 LPM and B20 9 LPM and there is marginal increase in CO emission. Similarly, Emission between B10 3 LPM and B20 3 LPM is compared similar marginal increase is observed. On the hand, emission between 9 LPM B10 Vs 3 LPM B10, as well as 9 LPM B20 Vs 3 LPM B20 is compared. Out of all the four blends, B10 9 LPM emits lower CO and highest is observed in B10 3 LPM. The increase in CO may be due to improper combustion due to rich mixture. However, since there is only a slight increase it is assumed that only some of the fuel did not combust properly [19].

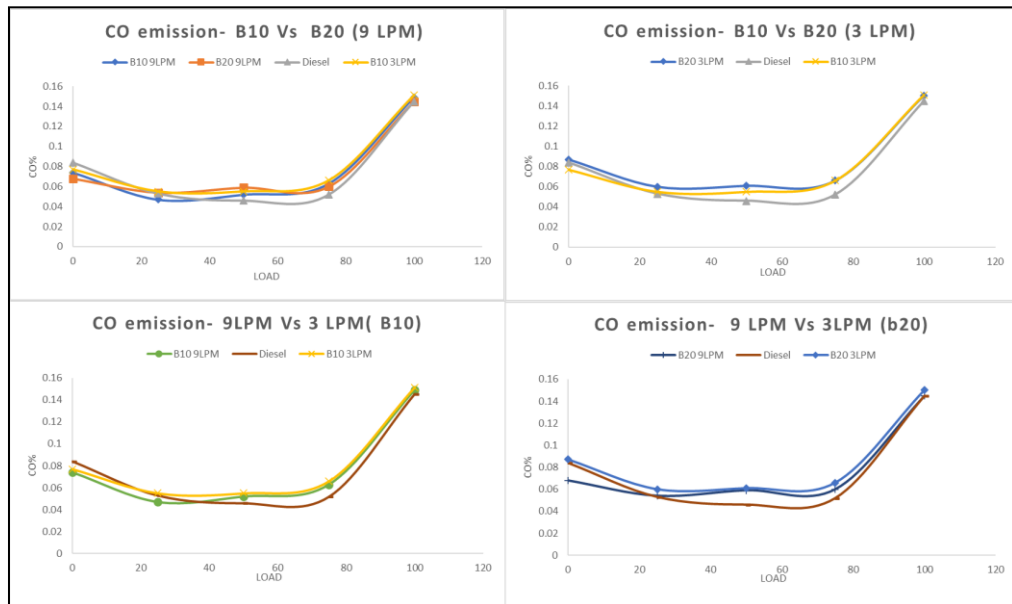


Fig. 5.1: CO Emission with respect to load

5.2 EMISSION OF HYDROCARBON (HC)

The emission of hydrocarbon is compared between various blends with that of pure diesel. Overall, it is significant that there is a slight increase in hydrocarbon emission. Figure 5.2 illustrates the unburnt hydrocarbon emission between B10 Vs B20 (9LPM), B10 and B20 (3LPM), 3LPM and 9LPM (B10) and 3LPM and 9LPM

(B20). It is observed, that the increase in hydrocarbons is due to inefficient combustion. Another possible cause could be, a surplus of hydrogen that refused to combust properly. As the flashpoint of hydrogen being potentially higher than diesel wherein surplus of hydrogen combined with the carbon emitted to form hydrocarbon.

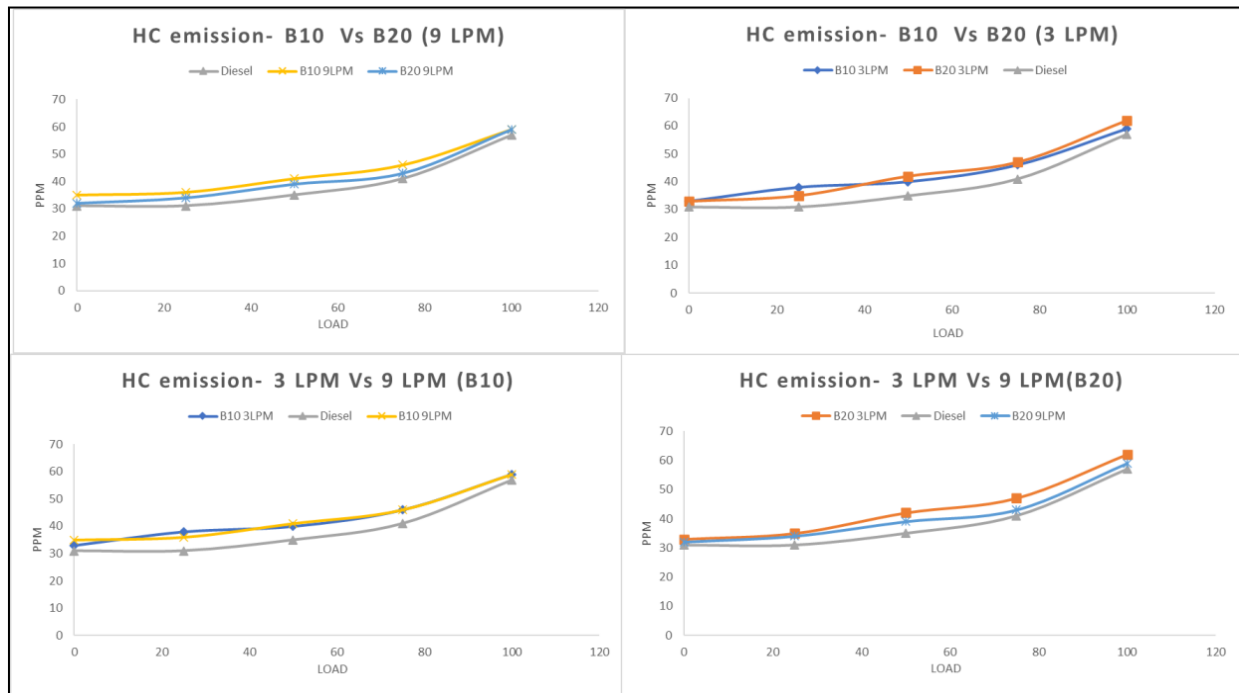


Fig. 5.2: HC Emission with respect to load

5.3 EMISSION OF NITROUS OXIDE (NO_x)

Figure 5.3 shows the comparison of nitrous oxide for various blends; B10 Vs B20 (9LPM), B10 and B20 (3LPM), 3LPM and 9LPM (B10) and 3LPM and 9LPM (B20). The formation of Nitrogen Oxide is mainly caused by high temperatures. NO_x production is influenced by the amount of N₂ and O₂. There is no significant rise in NO_x when the load is low. However, when the load exceeds 30%, there is a gradual increase in NO_x emissions compared to pure diesel, which could be attributed to the existence of exhaust gases from the previous cycle. However, Zheng et al. found that a lower ignition delay caused by a high cetane number may result in improper air-fuel blending and inefficient combustion [22].

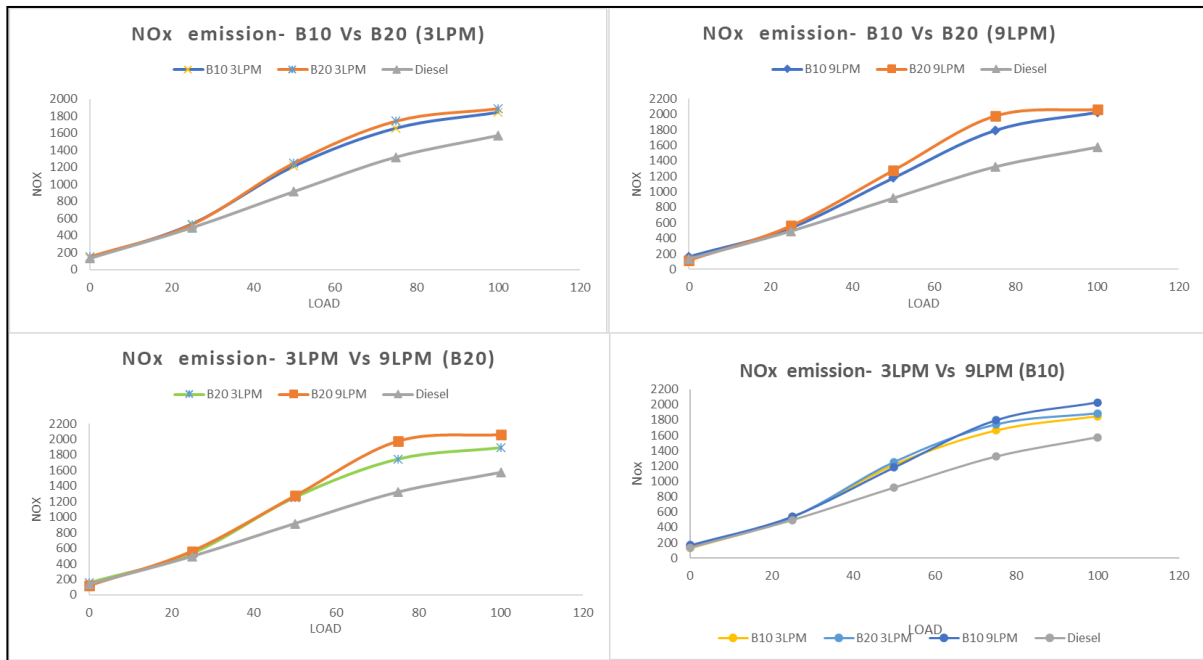


Fig.5.3: NOx Emission with respect to load

5.4 EMISSION OF CARBON DIOXIDE (CO₂)

Figure 5.4 depicts nitrous oxide comparisons for several blends; B10 vs B20 (9LPM), B10 and B20 (3LPM), 3LPM and 9LPM (B10) and 3LPM and 9LPM (B20). Overall, it is clear that there is decrease in carbon dioxide emission. Firstly, emissions of B10 3LPM and B20 3LPM are compared, and it is clear that the carbon emitted by both blends is similar to diesel, but there is a minor drop in beginning load condition when compared to diesel. Secondly, CO₂ emissions between B10 9LPM and B20 9LPM and shows that both blends emit less CO₂. This could be owing to the hydrogen infusion, as hydrogen has zero carbon content and complete combustion of hydrogen. Therefore, B10 LPM emitted lower carbon dioxide when compared to the other three blends.

5.5 BRAKE THERMAL EFFICIENCY (BTE)

The brake thermal efficiency of different blends; B10 Vs B20 (9LPM), B10 and B20 (3LPM), 3LPM and 9LPM (B10) and 3LPM and 9LPM (B20) are shown in the figure 5.5. On the whole, it is clear that there is drastically increase in brake thermal efficiency when compared to diesel. The high calorific value of hydrogen contained in the gas mixture, its high flame velocity, and the existence of atomic hydrogen and oxygen as in the high energy level equivalents all contribute to an increase in brake

thermal efficiency. As a result, when a hydrocarbon is burned, it tends to break down quickly into heavier hydrocarbons, resulting in a chain reaction.[19].

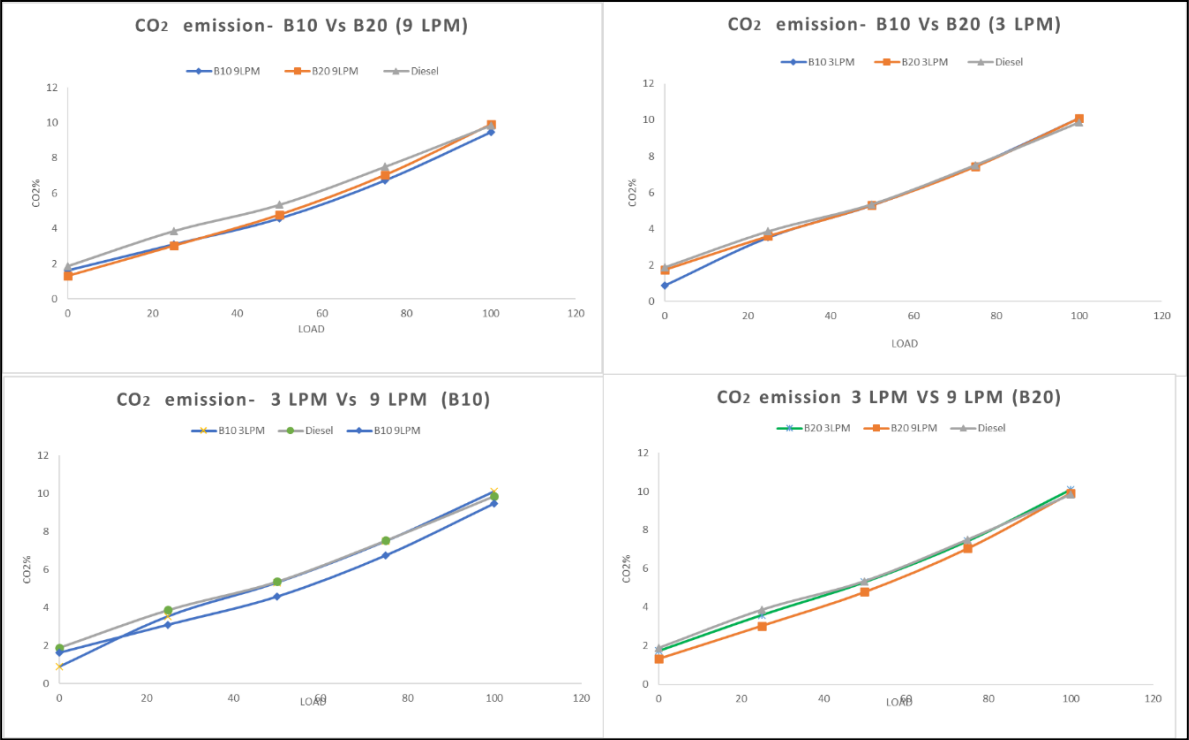


Fig. 5.4: CO₂ Emission with respect to load

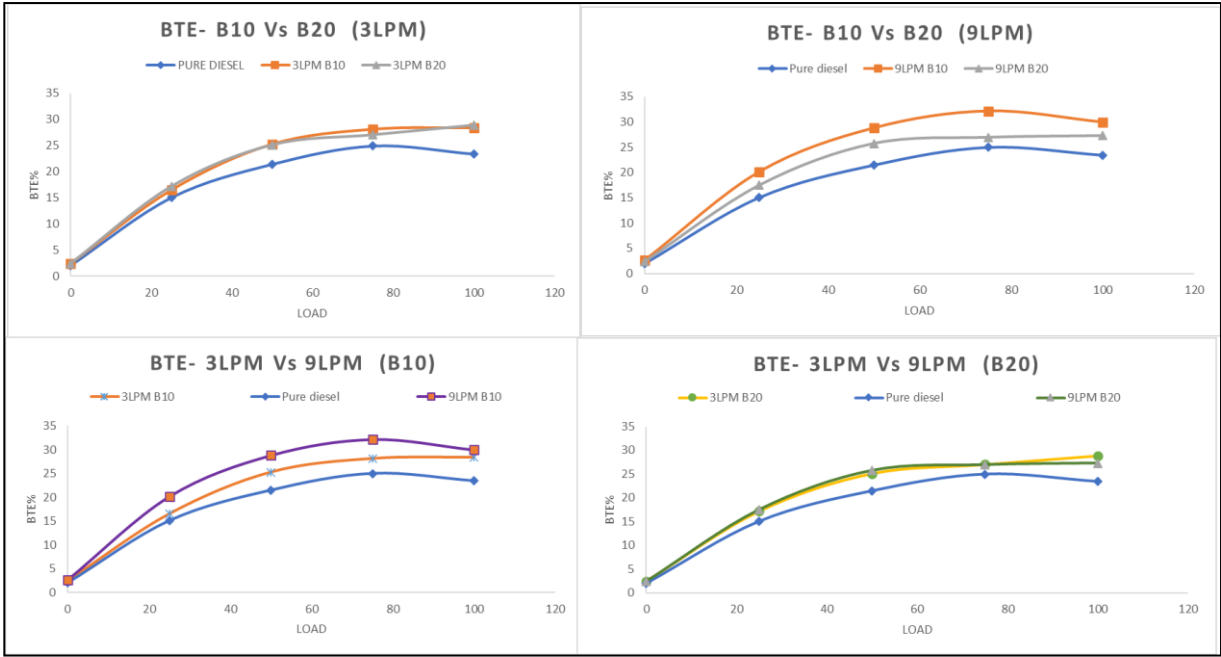


Fig. 5.5: Brake thermal Efficiency with respect to load

5.6 BRAKE SPECIFIC FUEL CONSUMPTION (BSFC)

The above figure 5.6 represent Brake specific fuel consumption. It is evident that there is a reduction in four blends B10 Vs B20 (9LPM), B10 and B20 (3LPM), 3LPM and 9LPM (B10) and 3LPM and 9LPM (B20). However, B10 9LPM proves to be a better blend out of all. The reduction in BSFC may be due to Catalyst which Eggshell or the higher density and viscosity of fuel. Moreover, due to hydrogen high calorific share which has resulted in better combustion.

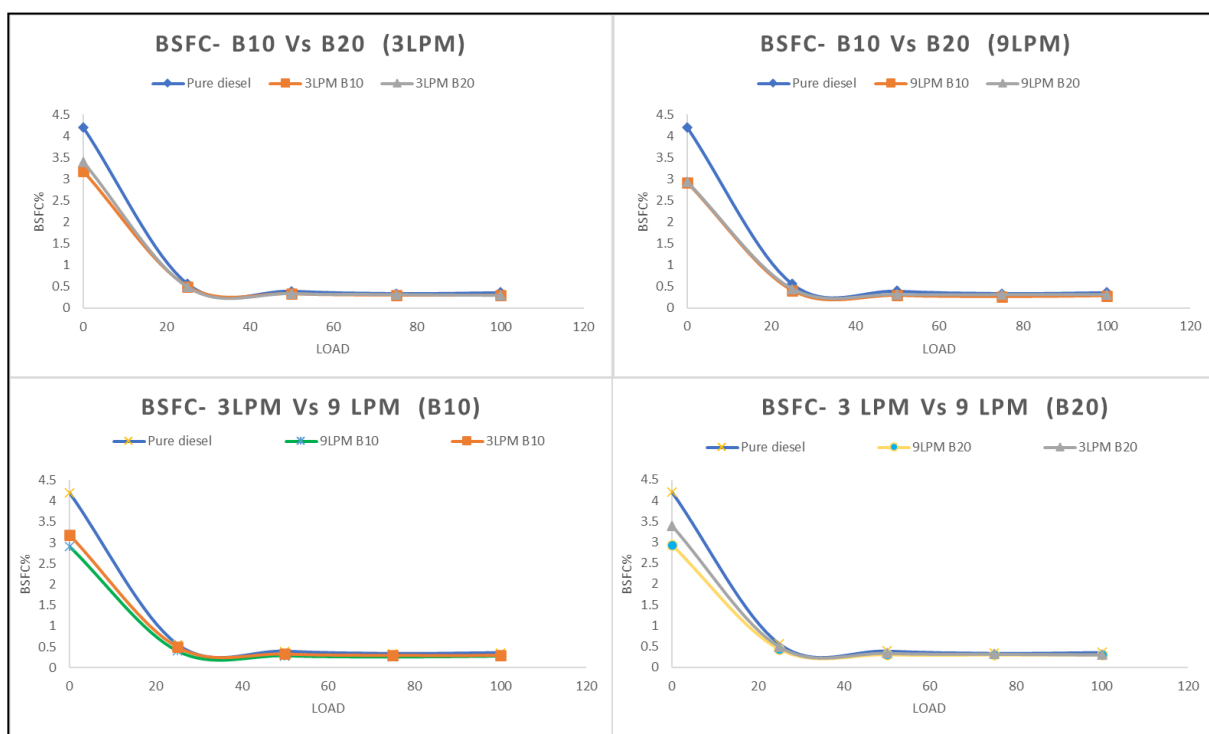


Fig. 5.6: Brake specific fuel consumption with respect to load

5.7 PRESSURE AND CRANK ANGLE

The above figure 5.7 represent various blends; B10 Vs B20 (9LPM), B10 and B20 (3LPM), 3LPM and 9LPM (B10) and 3LPM and 9LPM (B20), where Pressure and Crank angle is measured in 100% load. It is evident that there is an increase in pressure rate on all the four blends and B10 9LPM proves to be a better blend out of all. There is significant increase in pressure angle and this proves that the fuels have combusted properly and due to high flame velocity.

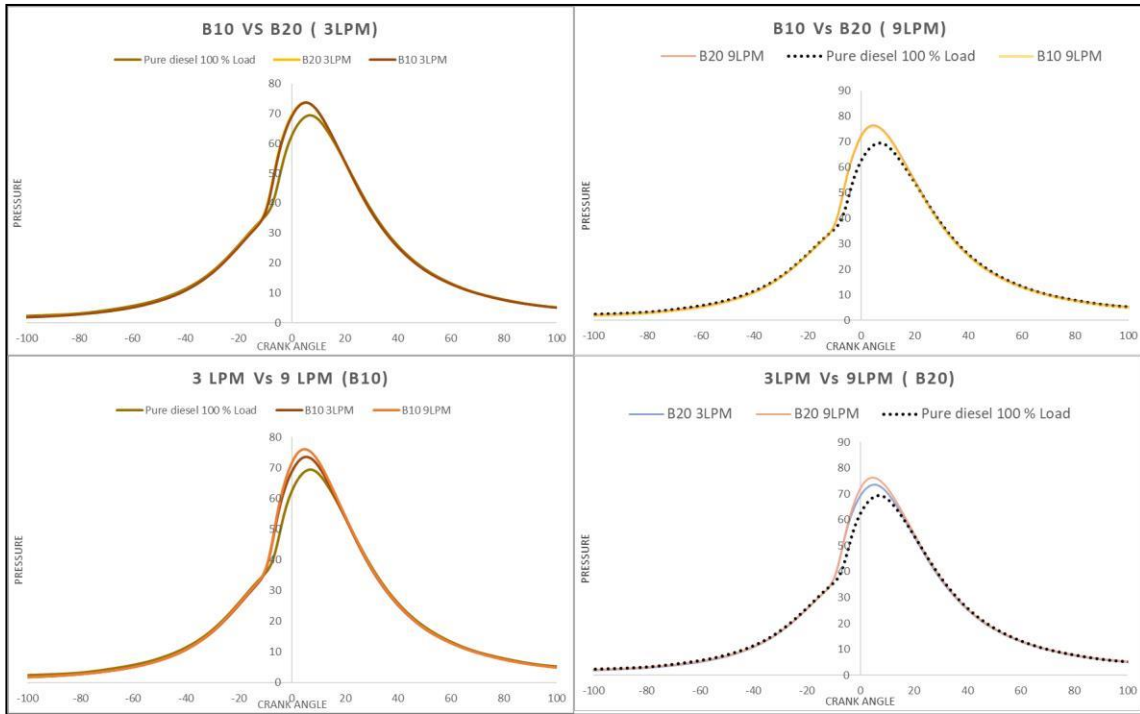


Fig. 5.6: Pressure and Crank angle consumption with respect to load

5.8 HEAT RELEASE RATE (HRR)

The above figure 5.8 represents the various B10 Vs B20 (9LPM), B10 and B20 (3LPM), 3LPM and 9LPM (B10) and 3LPM and 9LPM (B20) represent the heat release rate in 100 % load. Overall, it is clear that there is a drastically increase in HRR when compared to pure diesel. This due to hydrogen enrichment which has increase the HRR. Therefore, this proves that the fuel has combusted properly. Although, Heat release rate could be related with Pressure and crank angle as there an increase in increase in-cylinder there is an increase in HRR respectively.

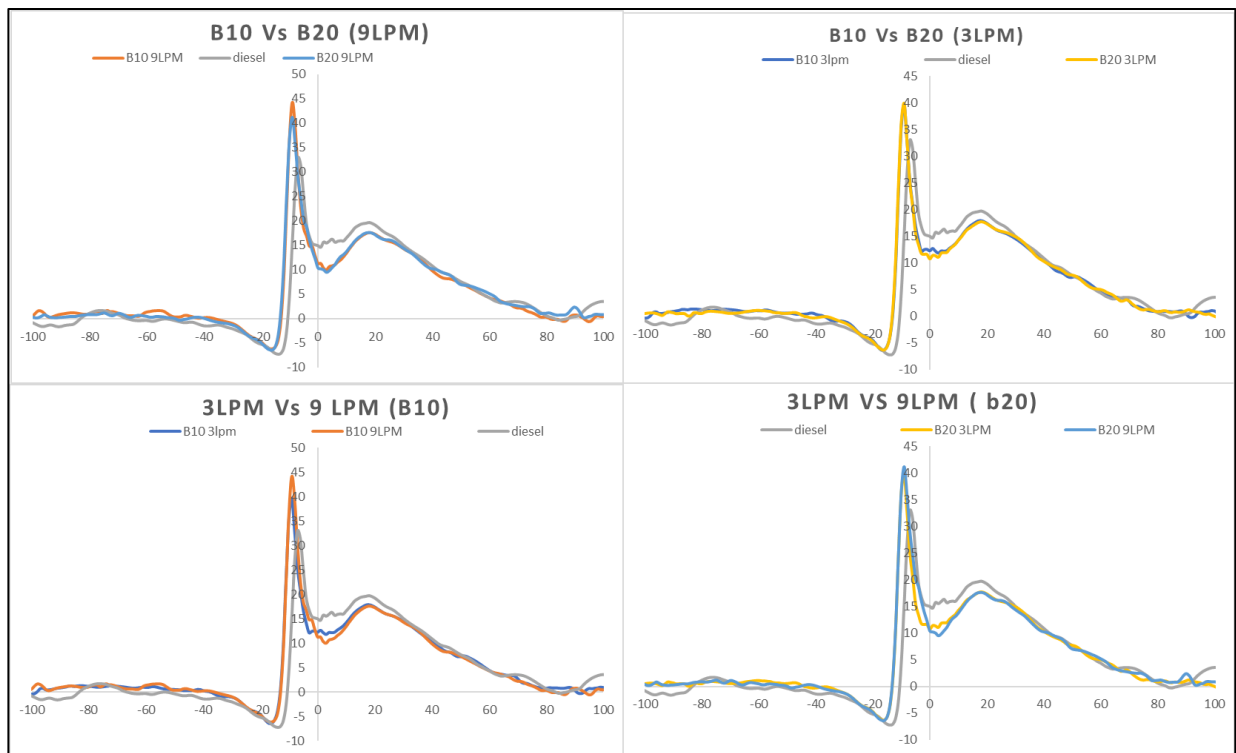


Fig. 5.8: Heat release rate

CONCLUSION

Egg shell was prepared and was calcinated at 800° C, SEM EDAX test was done in order to identify elemental and structural composition of the specimen. Then, bio diesel was synthesized using eggshell as heterogenous catalyst. Transesterification was done in the ratio of 1:13 of oil to methanol ratio. Wet processing was done to remove the excess amount of methanol present in the mixture and a yield of 92 % was obtained. Hydrogen enrichment was carried out, where hydrogen was injected through manifold in 3LPM and 9LPM respectively. Analysis of the fuel was done, where Combustion, emission and Performance was compared with that of pure diesel.

On the experimental investigation we can conclude that

- Eggshell contains high amount of Calcium Carbonate and use as catalyst when calcinated. Since Eggshell contains high amount of Oxygen content, it may improve the fuels performance characteristics
- Amount of catalyst used for transesterification was 3.5% wt. of the oil and a ratio of 1:13 of oil to methanol, thus obtaining a biodiesel yield of 92%.
- Through manifold injection emission parameters like Carbon monoxide, Hydrocarbon has experienced a marginal increase. And in both emission 9LPM blends has emitted lower amount of CO and HC when compared to 3LPM
- As compared to the other three blends, there is a noticeable reduction in carbon dioxide emissions when compared to pure diesel. B20 9LPM emits the least amount of carbon dioxide. Nitrous oxide has increased in all four blends; higher temperature causes formation of oxide of nitrogen. This due to hydrogen enrichment which has increased the temperature.
- When compared to pure diesel, there is a steady progression in Brake Thermal Efficiency, and 9LPM B20 has a high BTE when compared to all other blend.

- Brake Specific fuel consumption has lowered substantially with 9LPM B10 blend having the lowest specific fuel consumption.
- Overall, there is an increase in Pressure and crank angle with B10 9LPM blend having the highest-pressure crank angle.
- The HRR rate has grown dramatically, with B10 9LPM having the highest and B20 3LPM having the lowest. When compared to pure diesel, all four blends have greater HRR.

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