

Determination of thrust and study of emission characteristics on a turbojet engine using Alternate fuels

Submitted in partial fulfillment of the requirements for the completion of

PROJECT REPORT

By

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DEPARTMENT OF AERONAUTICAL ENGINEERING

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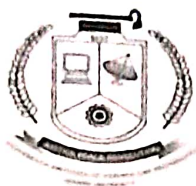
SATHYABAMA

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

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of JATIN GAJJAR (Reg. No.39260008), PRIYADARSHINI DASH (Reg. No. 39260023), who carried out the Project entitled "DETERMINATION OF THRUST AND STUDY OF EMISSION CHARACTERISTICS ON A TURBOJET ENGINE USING ALTERNATE FUELS" under our supervision from June 2022 to April 2023.

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I JATIN GAJJAR (Reg.No.39260008) on behalf of my team mate hereby declare that the Project Report entitled "DETERMINATION OF THRUST AND STUDY OF EMISSION CHARACTERISTICS ON A TURBOJET ENGINE USING ALTERNATE FUELS" done by me under the guidance of Dr.A.ANDERSON,M.E.,Ph.D., Dr.G.SENTHILKUMAR, M.E., Ph.D. is submitted in partial fulfillment of the requirements for the completion of Project.

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ABSTRACT

Candle nut oil was extracted from candle nut seeds by a crushing and filtration procedure. The transesterification process was carried out using two-step co-solvent esterification technique to create the candle nut biodiesel. Candle nut biodiesel's oxidation stability was shown to be poor, resulting in a increased acid value and the formation of insoluble gums and dregs. The similar process is used to transesterify soapnut oil which is obtained from soapnut seeds. This oil has greater oxidation stability than candlenut biodiesel. Due to higher cold filter plugging point of candlenut biodiesel and higher oxidation stability of soapnut biodiesel, combining them will produce a new type of alternate fuel which will improve engine performance while emitting fewer emission pollutants than other fossil fuels.

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LIST ABBREVIATIONS

SNME	SoapNut Methyl Ester
CNME	CandleNut Methyl Ester
CO	Carbon Monoxide
CO ₂	Carbon Dioxide
NO _x	Oxides of Nitrogen
O ₂	Oxygen
HC	Hydrocarbon
KOH	Potassium Hydroxide
CNO	Carbideoxidonitrate
CFPP	Cold Filter Plugging Point
ASTM	American society for Testing and Materials
FAA	Free Fatty Acids
BTE	Brake thermal efficiency
BSEC	Brake specific energy consumption
PAHs	Polycyclic Aromatic Hydrocarbons

CHAPTER 1

INTRODUCTION

By burning diesel contained in the earth's atmosphere, fossil fuels emit massive amount of CO₂ which in turn raises the earth's temperature and causes global warming, resulting in the greenhouse effect. To address these issues, we have a stand-in solution: alternative fuels. Alternative fuels, also known as non-traditional and advanced fuels, are any materials or substances that may be utilized as fuel rather than traditional fuels such as fossil fuels. Fuels are both extremely efficient and capable of great performance. Biodiesels are mainly low cost energy source since it can also be produced locally, it is a good alternative low cost energy source. Experiment results with biodiesel engine performance are not significantly different from those with pure diesel on diesel engine. The use of biodiesel in engines reduces Sulphur dioxide (SO₂) emissions, which are the principal cause of acid rain, and the superior lubricating properties improve engine life and efficiency. Biodiesel has a higher flash point than diesel and may be utilized in engines without modification, which increases operating safety. Biodiesel is a more portable renewable fuel that burns more efficiently. While biodiesel is more easily available than non-edible oils by more than 90%, these bio fuels represent no danger to the usage of edible oil. The aviation sector accounts for around 2% of total carbon dioxide emissions into the atmosphere. A lot of different airlines around the world have pledged to achieve carbon-neutral growth in international commercial aviation beginning in 2021, as well as a 50% reduction in CO₂ emissions by using sustainable aviation fuel (SAF). SAF is just biodiesel that is used in jet engines to decrease carbon footprints in the atmosphere. As a sustainable energy source, biodiesel can maintain a continuous supply chain.

Bringing in oil truly harms the economy in light of the fact that

the nation loses a lot of cash. It is time when nations should acknowledge the amount they've been spending on oil for a really long time since those costs have quit utilizing an elective wellspring of fuel will truly reduce the reliance upon imported as well as native fossil fuel.

1.1 EDIBLE OIL

Cooking oils are eatable oils. Eatable vegetable oil will be oil delivered from various natural products, seeds, oats, and nuts. They are capable of fat-solvent carriers. Sunflower and soybean oils incorporate polyunsaturated fats, while canola and olive oils contain monounsaturated fats. Palm seed oil comes from the seed, though palm oil comes from the meaty mesocarp of the palm natural product. Coconut oil contains up to 92% soaked unsaturated fats, making it entirely stable against oxidation and ideal for broiling. Olive oil is a top notch cooking oil that is likewise great for culinary applications. Soybean oil has a high grouping of polyunsaturated unsaturated fats and tocopherols. Canola oil is additionally called rapeseed oil, and it is removed from diminished glucosinolate and decreased erucic Brassica species. Sunflower oil comprises of a lot of unsaturated fats; 14%-39% oleic corrosive and 48%-74% linoleic corrosive. Sesame oil (*Sesamum indicum*) fundamentally contains monounsaturated unsaturated fats (45%-49%) and polyunsaturated unsaturated fat (37%-41%). Oil extraction is of two kinds: mechanical extraction as well as dissolvable or compound extraction. Dissolvable extraction is somewhat effective yet tedious.

1.1.1 Canola Oil

Canola oil biodiesel is a decent elective fuel, and enjoys incredible benefits contrasted and other biodiesel fills. Canola oil is created by Canola seeds otherwise called *Brassica napus*. Other than the US, it is filled in Canada and Australia as well as in Europe and China (yet the yield is designated "two-fold low rapeseed," alluding to its low degrees of

erucic corrosive and glucosinolates, in the last two nations). It contains around 40-45% oil which is higher than other oil seeds.

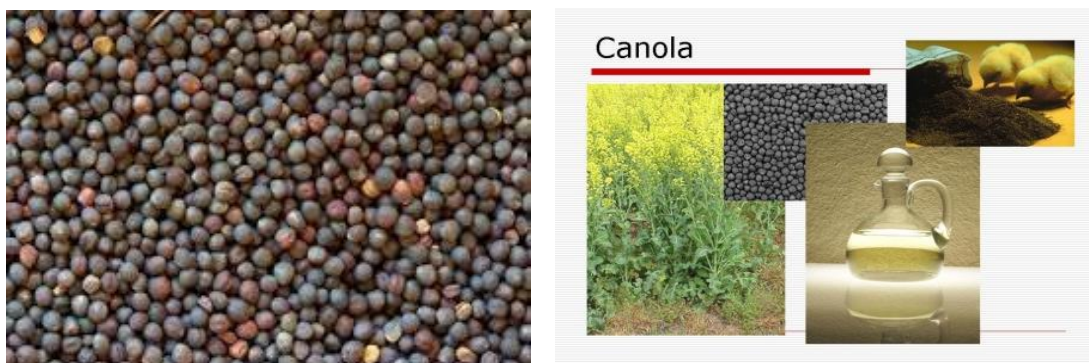


Figure 1.1: Canola Seeds and Oil

Canola biodiesel blends showed indistinguishable warm dauntlessness (180°C) but significantly higher oxidative robustness (183°C versus 258°C) after the consolidation of the manufactured compound tert-butylhydroquinone. The preliminary revelations from this study displayed a huge development in the warm and oxidative consistent quality of canola biodiesel blends using ordinary expansions. The epoxidase canola biodiesel blends' warm robustness diminished. The seeds contain 43% oil, more than two times whatever amount of soybean oil. Since it can cross-prepare with brassica yields and spread huge quantities of comparable diseases, canola isn't well known everywhere. Besides, nitrous oxide, which has on various occasions more impact than carbon dioxide, is conveyed by canola.

1.1.2 Sunflower Oil

Sunflower (*Helianthus annuus* L) is one of the world's leading oilseed crops. Sunflowers are local essentially to North and South America and a few animal varieties are developed as ornamentals for their breathtaking size and bloom sets out and toward their consumable seeds. The seeds are reaped from the plant's huge bloom heads, which can gauge more than 12 inches (30.5 cm) in distance across.



Figure 1.2: Sunflower Seeds and Oil

A solitary sunflower's head might contain up to 2,000 seeds. There are two primary kinds of sunflower crops: one sort is developed for the seeds you eat, while the other which is the greater part, is cultivated for the oil. The sunflower seeds you eat are encased in unpalatable highly contrasting striped shells, likewise called bodies. Those utilized for separating sunflower oil have strong dark shells. Sunflower seed and part at different dampness contents territory between 4 - 20%. Sunflower seeds are particularly high in vitamin E and selenium. These capability as cell reinforcements to safeguard your body's cells against free extreme harm, which assumes a part in a few ongoing sicknesses. sunflower seeds are a decent wellspring of helpful plant compounds, including phenolic acids and flavonoids which likewise capability as cell reinforcements.

1.1.3 Soybean Oil

Soybean, (*Glycine max*), additionally called soja bean or soya bean is the yearly vegetable of the pea family (*Fabaceae*) and is a consumable seed. The soybean is a yellow vegetable that comes from China and is the foundation of human and creature eats less carbs in numerous Oriental nations because of its high healthy benefit and minimal expense.



Figure 1.3: Soybean Seeds and Oil

Developed soybean seeds have an oil content of roughly 18-22%, while wild soybean seeds contain around 8-10% oil. Contingent upon the route and developing states of the soybean, its grain contains 30-48% protein and 17-26% fat. Soybeans contain 20-25% of carbs, 4-5% of debris components (counting calcium, phosphorus, potassium, sodium, iodine, molybdenum, and so forth), nutrients (E, V1, V2, V6, pantothenic corrosive, choline, folate, biotin and b.) happen. The transesterification response yields methyl or ethyl esters (biodiesel) and a side-effect of glycerin. A 2009 life cycle investigation of biodiesel done by the USDA found that soy biodiesel yields 4.56 times the fossil energy expected to create it. In correlation, petrol diesel has a fossil energy proportion of 0.84.

1.1.4 Groundnut Oil

Groundnut oil otherwise called *Arachis hypogaea* is found in India in the provinces of Andhra Pradesh, Tamil Nadu, Maharashtra and Madhya Pradesh being the main maker of groundnut. Groundnut develops in Asia with 11.6 m ha (47.15%), and Africa, with 11.7 m ha (47.56%), hold greatest worldwide region under groundnut.



Figure 1.4: Groundnut Seeds and Oil

Non-industrial nations in Asia, Africa and South America represent more than 97% of world groundnut region and 95% of all out creation. Peanuts contain 13 unique nutrients including A, B, C and E gatherings, 26 fundamental minerals like iron and calcium, zinc and boron. The groundnut seed parts with in excess of 60% germination were found to have oil with superb fuel properties. It was likewise found that the above seed parcel can be appropriate for antacid based single-step transesterification process because of lower free unsaturated fat ($< 1.8\%$). Groundnut oil has been accounted for of having ability to create around 123 gallons of biodiesel per section of land while soybeans yield just 50 gallons. The outcomes showed that groundnut seeds gave oil yield of 45.3%, while trans-esterification yielded 86.8% groundnut oil ethyl ester on a volume premise. At 40°C , higher thickness of $39.2 \text{ mm}^2/\text{s}$ was gotten for crude groundnut oil than $7.60 \text{ mm}^2/\text{s}$ acquired for groundnut oil ethyl ester. Crude groundnut oil has a consistency of $39.2 \text{ mm}^2/\text{s}$ at 40°C contrasted with $7.60 \text{ mm}^2/\text{s}$ for groundnut oil ethyl ester.

1.1.5 Palm Seed Oil

Palm seeds are otherwise called attap seeds. They are the juvenile products of the nipa palm or "mangrove palm", which fill in delicate mud and sluggish flowing and stream waters.



Figure 1.5: Palm Seeds and Oil

Palm seeds are otherwise called canariensis seeds which have oil content of 10.36%, The carb is about 72.59%, the protein content about 5.67% and dampness 10.20%. The significant supplements (mg/100 g of oil) decided were: potassium (255.43), magnesium (62.78), calcium (48.56) and phosphorus (41.33). Seeds at first contain 3.1-7.1 wt. % dampness, which can build up to 15-20 wt. % after such dousing and washing. The seeds should be dried before oil extraction as the dampness can in any case cause waste in the oil test, and the dried seeds are far more straightforward to crush.

1.2 NON EDIBLE OIL

Non-edible oils are not appropriate for human food on account of the presence of a few harmful components. Non consumable oils are primarily wastage and Side-effects of Edible/Cooking oil and Treatment Industry and oils of a few non-consumable animal varieties seeds. Major Non eatable oil seeds are Candlenut, Soapnut, karanja, Jatropha, Castor and Neem.

1.2.1 Jatropha Oil

Jatropha curcas, a dry spell lenient and versatile plant, has been found and is a potential perpetual energy crop for the jungles and subtropics and the seeds of this plant can be utilized to make biodiesel. It is broadly utilized in semi-developed and wild conditions all through Focal America, India, South America, Africa, and South East Asia.



Figure 1.6: *Jatropha* Seeds and Oil

Kernels can contain somewhere in the range of 47.10% to 59.32% oil. The qualities of biodiesel fuel expected from the unsaturated fat piece of oils, for example, kinematic consistency (4.8 mm²/s), thickness (880 kg/m³), cold channel stopping point (−3°C), and cetane numbers (38-51), were in concurrence with EN-14214 principles. It is hurtful to the two individuals and creatures. In spite of the prominence of *Jatropha*, there are nearly nothing and ambiguous yield and execution information accessible for this plant specie

1.2.2 *Castor Oil*

Castor is a dry season lenient plant seed that is said to have begun in Abyssinia. It flourishes in moderate environments and might be seen as across the tropical and subtropical world. India is the world's driving maker of castor oil, representing 60% of all out overall result. As indicated by writing, the initial 2-3 years of pay from *jatropha* crops are genuinely low.



Figure 1.7: Castor Seeds and Oil

Intercropping with castor might help you earn more money in the beginning since it produces more crop in less time than *Jatropha*. This would upgrade the business suitability of castor and *jatropha* estates from an economic stance. Notwithstanding the high kinematic consistency of transesterified castor oil (252.088 mm²/s), This would upgrade the business suitability of castor and *jatropha* estates from an economic stance. Notwithstanding the high kinematic consistency of transesterified castor oil (252.088 mm²/s), which is genuinely like other vegetable oils, and crude castor oil's high thickness (585) makes it reasonable for a biodiesel mix. The sole oil can break down in liquor, and dissimilar to other vegetable oils, it needn't bother with to be warmed or use as much energy to become fuel. Low sulfate content (0.04%) and a 2600°C blaze point are further qualities of modern importance.

1.2.3 *Karanja Oil*

Karanja (*Ponagamiapinnata*) is mainly found in the humid climate and is a medium-sized plant which is mainly found in the lowlands of Australia, the Philippines, and Malaysia.



Figure 1.8: Karanja Seeds and Oil

The scope of seed weight varieties for 100 seeds was determined to be 39.8-229.5 g, while the scope of seed oil content was 9.5%-46%. Likewise, the oil content went from 32.6% to 44%. This plant is viewed as a dry spell lenient animal types since it adjusts to an assortment of soil types and alkaline circumstances. Trans-esterified Karanja oil has a calorific value of 34 MJ/kg, a cloud point of 70 °C, a flash point of 2400 °C, and a kinematic viscosity of 32.1 mm²/s.

1.2.4 Soapnut Oil

Soap nut is a fruit of the soap nut tree that grows in tropical and subtropical climates around the world, including Asia, America, and Europe. In India, Nepal, Bangladesh, Pakistan, and many other countries, two separate species (*Sapindus mukorossi* and *Sapindus trifoliatus*) are extensively accessible. Soap nut oil has been identified as a non-edible oil with high potential for biodiesel generation from a waste item. The primary goal of this research is to employ industrially used coal-fired boiler waste as a catalyst in the synthesis of biodiesel, cutting the cost of manufacturing while also eliminating environmental difficulties.



Figure 1.9: Soapnut Seeds and Oil

Soapnut oil has an unusually high concentration of monounsaturated fatty acids. The amazingly high of monounsaturated unsaturated fats in soapnut oil is particular in examination with the normal unsaturated fat profiles of vegetable oils. As indicated by its unsaturated fat acid, soapnut oil biodiesel possibly shows agreeable properties concerning the biodiesel determination.

The strong saturating property of the soapnut keeps the skin all around hydrated, forestalls drying of the skin and making the skin look brilliant and graceful. Moreover, the strong antibacterial and calming properties deal with skin issues like skin break out, acne, eczema, dermatitis and psoriasis. The reasonability of delivering biodiesel from soapnut (*Sapindus mukorossi*) oil was investigated as far as fuel attributes and diesel mixing characteristics. Soapnut oil methyl esters (SNME) showed satisfactory fuel attributes, with methyl oleate representing 55.2 wt.% and methyl eicosenoate representing 23.9 wt.%. The cetane number of the SNME was 58, the cold filter plugging point was 6 °C, the flash point was 180 °C, the iodine value was 83.6 g I₂/100 g, and the kinematic viscosity was 2.18 cSt at 40 °C. Also, the SNME's oxidation stability met the standards of the biodiesel boundaries. Likewise, the Transesterified soapnut fuel was blended in with diesel at different volumetric rate and the fuel attributes were contrasted with the necessary standards. Furthermore, the SNME was blended with diesel at various proportions and evaluated for fuel properties in contrast with the relevant specifications. The direct relationships were laid out to depict the varieties of the properties of the Soapnut biodiesel.

1.2.5 Candlenut Oil

Aleurites Moluccana, often known as candlenut, is an evergreen tree that may grow to be up to 20 metres tall. Its roots may be traced back to the Indo-Malaysian area, although it is currently found across the tropical regions. It has been naturalised in India and may be found in abundance in portions of South India and the state of Assam. The tree's limbs are widely spaced and uneven, generating a huge spread crown at the top. The bark is smooth, dark, and has noticeable vertical lines.



Figure 1.10: Candlenut Seeds and Candlenut Oil

The leaves of *Aleurites Moluccana* are oblong to lanceolate or widely rhomboid. Candlenuts are around 4-6 centimeters wide and have an exceptionally hard shell which can't be stripped manually. They are very slick, which is the reason they can likewise be burned when they are integrated, subsequently the English name Candlenut. It's a tropical tree which can likewise be held as a houseplant. There is a conventional technique: Press the seeds in the ground and cover them with low, dry passes on estimating 3 to 10 cm. Later, consume the leaves and toss the hot seeds into cold water. The pericarp ought to break now. Breaking the seeds with a nutcracker is likewise conceivable. The yearly candlenut seed yield is around 16 tons for every ha, and the yearly oil yield is roughly 3200 kg ha⁻¹. Candlenut seed contains 30-60% candlenut oil, and the oil might be removed from the seeds utilizing an assortment of extraction strategies. Candlenut oil contains a ton of iodine (≥ 125) and a lower pour point. In this report, a two-step co-dissolvable strategy for BDF creation from CNO was

analyzed. First and foremost, esterification of free unsaturated fats (FFAs) (0.22 wt. %) present in CNO was done utilizing a co-dissolvable of acetonitrile (30 wt. %) and H₂SO₄ as an impetus wt. %. The CNME had the cetane number of 34, cold filter plugging point of - 8°C, flash point of 125 °C, iodine value of 0.4 g, and kinematic viscosity of 2.21cSt at 40 °C. Moreover, the CNME's oxidation stability met the criteria of the biodiesel parameters. In addition, the CNME was mixed with diesel at various volumetric percentages and the fuel attributes were compared to the necessary standards. To explain the differences in the attributes of the CNME-diesel blends with the volumetric % of the CNME, linear correlations were created.

1.2.6 Mahua Oil

The Mahua (*Madhuca indica*) tree develops to a level of approxiamte 20 meters. It fills generally in India, Pakistan, Bangladesh, and Malaysia. It is a quickly developing evergreen or semi-evergreen tree that might be established in both warm and sticky environments.



Figure 1.11: Mahua Fruit and Dried Mahua

In India, the expected result of mahua seed is around 60 MT each year. The oilseeds and oil yield in mahua crops vary with mahua tree development. In

general, the complete oilseed output each year from mature mahua trees fluctuates from 20 to 200 kg ha¹, with a total oil yield each year extended time of generally 2.7 tons per ha. The calorific value of mahua seed oil is expressed to be 38.5 kJ kg¹, which is 14% lower than the calorific value of mineral diesel (42 kJ kg¹).

1.2.7 Kusum Tree Oil

The kusum tree is approximately about medium to large-sized tree that may reach heights of 35 to 45 feet. Kusum seeds have an oil content ranging from 51-62%.



Figure 1.12: Kusum Tree

Kusum oil isn't viewed as consumable since it contains harmful cyanogenic compounds. Kusum oil is composed of around 40% unsaturated fatty acid and 53% saturated fatty acid.

1.2.8 Rubber Tree Oil

The rubber tree, otherwise called the para rubber, is local to Brazil's Amazon tropical forest. Malaysia, Indonesia, India, Thailand, Sri Lanka, and Liberia all have rubber trees.



Figure 1.13: Rubber Tree

Rubber trees might develop to arrive at up to 34 m tall, with rubber seeds weighing between 2-4 g. A regular ranch contains 350-500 trees for every hectare and produces 100 to 150 kg ha⁻¹ rubber seeds every year. Rubber seed oil is dull, and the oil content in rubber seeds and portions ranges somewhere in the range of 40 and 60% by weight. Rubber seed oil has a more prominent unsaturated fat focus than vegetable oils, at generally 17%. The primary unsaturated fat creations of rubber seed oil incorporate stearic acid, oleic acid, palmitic acid, linoleic acid and oleic acid.

1.3 PROBLEM STATEMENT

- The primary goal of this project is based upon making biofuel which can easily replace any depleting jet fuel or fossil fuel which will give us a better and brighter future. Using biodiesel also will help us with the reduce emission which will result in lower greenhouse gas effect.
- At lower and sub zero temperatures, the oil filter tends to choke as oil becomes more viscous or glacial. This property is called Cold Filter Plugging point which should be sufficiently low to ensure low

temperature operability. Another aspect is the oxidation stability which means the hours taken for the fuel to completely vapourize. The less the oxidation stability the more easily the fuel vapourizes.

- Ideal biodiesels should have least CFPP and higher oxidation stability to make the fuel feasible and efficient.

1.4 PROJECT OBJECTIVE

- The main aim of this project is to prepare a biodiesel with 2 different kinds of biofuel blend which will provide equal or more amount of thrust with stable property using biofuel and to operate the engine with no changes to get the lowest possible emissions.
- The soap nut biodiesel has better oxidation stability than candlenut biodiesel, and similarly, candlenut biodiesel has a higher cold filter plugging point than soap nut biodiesel, depending on the quantity of saturated fat.
- To find out physical and chemical properties such as density, kinematic viscosity, flash point, fire point of blended biofuels.
- To blend the biofuels with diesel to form combinations of B5 and B20 and test them for oxidation stability and CFPP.
- To test the biodiesels in a Jet engine to determine equal or more amount of thrust as compared to fossil diesel and its mass flow rate.
- To determine best of two blends based on lower emission characteristics, better mass flow rate and amount of thrust increased as compared to fossil diesel.
- The initiative intends to minimise hazardous emissions during the burning of biofuel, which is almost devoid of sulphurous carbon dioxide compounds, hence lowering greenhouse gas emissions.

CHAPTER 2

LITERATURE REVIEW

2.1 LITERATURE BASED ON BIODIESEL

In the future, biodiesel has the potential to replace petroleum-derived diesel as a source of energy, and it may be utilized in existing diesel engines without requiring any modifications. In current times, the agriculture sector provides easy access to edible oil on a huge scale, which is used to manufacture more than 95% of the world's biodiesel.

M. M. Gui et al. (2008) studied that without adequate planning, the ongoing and massive production of biodiesel from edible oil may have detrimental effects on the world, such as the depletion of the food supply and the resulting economic imbalance. Utilizing non-edible oil or used edible oil (WEO) could help solve this issue. The second concern in this situation is whether utilising non-edible oil can make up for the drawbacks of using edible oil.

Yi-Hung Chen et al. (2011) studied non-edible vegetable oils, mostly produced by seed-bearing trees and shrubs, could be an alternative oil sources. It appears that the high cold filter plugging point of soapnut oil biodiesel and the poor oxidation stability of jatropha oil biodiesel can be successfully enhanced to meet all biodiesel standards at the ideal blending ratio. To assess the differences in fuel qualities, the ideal biodiesel mix was further mixed with diesel at different volumetric percentages. The fuel characteristics of the biodiesel-diesel blends up to B40 are satisfactory.

In addition, the rising emissions of dangerous pollutants and greenhouse gases have led to environmental issues. Consequently, it is essential to use clean energy sources, including biodiesel. Considering the importance of this topic, Khairul Azly Zahan et al., (2018) paper focuses on the use of palm oil, its by-products, and mill discharge for biodiesel production. Because biodiesel possesses characteristics that are similar to those of ordinary petro-diesel, palm

oil is regarded as a superior raw material. Numerous experiments have been done to use palm oil's byproducts and mill runoff as raw materials due to the controversy over whether it should be used as food or fuel. The characteristics of biodiesel, the distinction between palm-biodiesel and other biodiesel sources, and the viability of using palm oil as the main component of future sustainable and alternative energy sources are also covered in this study.

G Antony Casmir et al., (2021) studied that diesel is the fuel that is most frequently used in motor vehicles, farmland, and the energy industry, which has an impact on global warming and health issues. The main source of air pollution is the smoke exhaust particles from diesel engines. This sparked an increased interest in looking for alternatives to petroleum-based energy. As a renewable energy source, biodiesel has mostly replaced diesel fuel in compression ignition engines without requiring any engine modifications. Due to its greater availability, edible oil is used as a biodiesel at a rate of over 90% when compared to non-edible oils. The use of significant quantities of edible oils as biodiesel may result in food supply shortages, depletion, and economic issues. Use of non-edible oil or used cooking oil can help to prevent this.

2.2 LITERATURE BASED ON COLD FILTER PLUGGING POINT AND OXIDATION STABILITY

Many authors have studied some aspects influencing cold parameters of biodiesel such as oil composition as studied by María Jesús Ramos et al., (2009). A. Kleinová et al., (2007) noted that the presence of unsaturated esters improves cold properties of biodiesel but worsens oxidation properties.

Marta Serra et al., (2013) studied the oxidative stability of biodiesel from various feedstocks was increased by using citric acid (0.1 M) in the purification stage rather than distilled water, and as a result, the amount of washing agent needed was decreased. For all of the evaluated antioxidants, the use of citric acid as a washing agent increased the Rancimat oxidation stability within the range of 250-1000 ppm. The findings in this instance appear to be unrelated to the washing agent employed. In comparison to plain samples, the antioxidant

hardly changed the IP values of citric acid washed samples.

The research on biodiesel stability by M. M. Rashed et al., (2015) studied that in Rancimat equipment model 743, the oxidative stability of biodiesel from various feedstocks and their mixes with various dosages of antioxidants were examined. The Rancimat Method involves passing a stream of filtered air at a rate of 10 l/h to cause oxidation.

K Yamane et al., (2007) in his paper noted that using the Rancimat test method, methyl esters with various unsaturated fatty acid components underwent an accelerated oxidation stability test. The stability of heat and auto-oxidation processes as well as oxidation degradation are significantly influenced by the unsaturated fatty acid constituents. The current study has demonstrated the impact of biodiesel oxidation on the characteristics of diesel combustion and emissions, as well as the influence of the biodiesel oxidation on quality parameters such as peroxide value, acid value, kinematic viscosity, and induction period obtained during a Rancimat test.

Gaurav Dwivedi et al., (2016) studied that the flask containing 60 ml of demineralized or distilled water and an electrode for measuring conductivity is filled with the vapours created during the oxidation process of the 5 ml biodiesel sample that has been kept at a constant temperature. A measurement and recording equipment is linked to the electrode. When the conductivity starts to quickly rise, it signals the end of the induction phase. The volatile carboxylic acids created during the oxidation process and absorbed in the water are what's causing this fast growth. The good characteristic value for the oxidation is provided by an oxidation curve that is produced when the conductivity of this measurement solution is continually recorded. The point of inflection is known as the induction.

2.3 LITERATURE BASED ON COMBINED BIODIESEL

An experimental study was carried out by Manigandan S. et al., (2021) for evaluating the efficiency, noise, and emission properties of a two-cylinder diesel engine running on a combination of canola and moringa oleifera. The obtained results unequivocally demonstrate that adding M. oleifera and canola to biodiesel blends not only improves performance but also functions as an antioxidant ingredient.

Sunflower and soybean oil mixture was utilized for the production of biodiesel. Biodiesel and its blends show minimum HC, CO and CO₂ Emissions is seen as studied by Medhat Elkelawy et al., (2020).

Rakesh Sarin et al., (2007) studied that Jatropha biodiesel produces a composition with effective and improved low temperature properties as well as good oxidation stability when combined with palm methyl ester. To improve oxidation stability and low temperature qualities, the feedstock used to make biodiesel must include a sufficient ratio of saturated and unsaturated fatty components. Jatropha biodiesel has good low temperature characteristics but weak oxidation stability. Palm biodiesel, on the other hand, has poor low temperature qualities despite having strong oxidative stability. When Jatropha and Palm are combined, these two crucial biodiesel qualities are improved. It was shown that blending Palm oil biodiesel with Jatropha biodiesel at a concentration of about 20–40% could reduce the amount of antioxidants needed by 80–90%. The addition of Jatropha biodiesel enhances the low temperature characteristics of palm biodiesel, which are bad in terms of cloud point and pour point. Therefore, a synergistic combination with higher oxidation stability and low temperature property can result from the optimal combination of Jatropha biodiesel and palm biodiesel. When compared to baseline diesel at full load, the experimental analysis shows a marginal reduction in BTE of about 2%, BSFC was higher by 3%, EGT increased by 3%, CO₂ was higher by 0.86%, CO reduces by 0.029%, NO_x reduces by 8%, and HC decreases by 12 PPM.

Medhat Elkelawy et al., (2020) studied a blend of sunflower and soybean oils. The emissions of HC, CO, and CO₂ from biodiesel and its blends are minimal. For all biodiesel mixes, a corresponding decrease in brake thermal efficiency (BTE) and brake specific energy consumption (BSEC) is seen. The findings indicate that the examined fuel blends had higher CO₂ emissions than diesel fuel. The homogeneous catalysed transesterification technique was used to create biodiesel from a new blend of sunflower/soybean with a 50:50 V/V% oil ratio. Under various engine load situations and a Journal Pre-proof 30 fixed engine speed of 1400 rpm, the impacts of the investigated fuels on DI-engine combustion, performance, and emissions were studied in the lab. The D50B50N000 biodiesel mix lowers the CO and UHC exhaust pollutants. However, as compared to diesel fuel, it magnifies the NO_x and CO₂ emissions. Using AgSCN, SCP1 as a nano addition has been estimated to significantly reduce CO, UHC, and NO_x emissions, with the decrease increasing when the volumetric percentage of H₂O₂ is increased in comparison to both pure diesel and biodiesel blends. The CO₂ emissions from the nano blend fuel D50B50N200 and the nano emulsion mix fuels dramatically rise, with D50B50+4% H₂O₂ having the highest value among all tested fuels, according to the data. The highest BTE ratio, 27.16%, is found in the biodiesel blend D50B50N200+4% H₂O₂, which has a little lesser BTE than diesel fuel. Results obtained indicate that D50B50N200, a nano blend fuel, and the nano emulsion blend fuels considerably increase CO₂ emissions, with D50B50+4% H₂O₂ having the highest value among all tested fuels. While D50B50N200+4% H₂O₂ has the greatest BTE ratio of 27.16%, D50B50N000 has a little lower BTE than diesel fuel.

2.4 LITERATURE BASED ON BIODIESEL PERFORMANCE

A great deal of scientists claimed that while short-term engine testing utilizing biofuel as fuels were extremely encouraging, the findings of long-term studies revealed higher carbon buildup and contamination of lubricating oil, which led to engine failure. They came to the conclusion that vegetable oils needed to be chemically changed or combined with diesel to stop the engine from failing.

It was reported in (Syed Ameer Basha 2008) paper that biodiesel has similar combustion properties to diesel and that blends have a short ignition delay, higher ignition temperature, higher ignition pressure, and a higher peak heat release. It was discovered that the engine power output matched that of diesel fuel. Furthermore, it found that base catalysts and enzymes are more efficient than acid catalysts and enzymes. They also came to the conclusion that while modified sunflower oil can be utilised as a fuel for diesel engines, raw sunflower oil cannot.

Oyetola Ogunkunle et al., (2019) studied the benefits of biodiesel are well known and in recent years, the world's production capacity has grown at a double-digit annual rate. Future efforts should concentrate on producing 100% biodiesel as a result. When palm methyl ester and jatropha biodiesel are combined, the result is a composition with better low temperature performance and good oxidation stability.

Sujata Barhma et al., (2022) studied that to obtain increased oxidation stability and low temperature qualities, the feedstock for the production of biodiesel must have a sufficient ratio of saturated and unsaturated fatty molecules.

Anderson A et al., (2021) studied the higher cetane number of diesel in comparison to other combinations affects the enhanced brake thermal efficiency. Every mix reported BSFC values higher than diesel. The blends CN10 + 90SN, CN90 + 10SN, and CN50 + 50SN, for example, reported 6%, 10%, and 11% higher than neat diesel, respectively. In comparison to all other diesel fuel, the high oxygenated biodiesel and high combustion temperature have a lessened impact on the carbon monoxide emission, hydrocarbon emission, and smoke density of biodiesel. Compared to regular diesel fuel, the increased oxygen content of biodiesel has a greater influence on its nitrogen emissions.

Another literature review by Anderson A et al., (2021) concluded that the greatest option as a diesel replacement fuel without modifying engine specifications is a B20 blend of blended biodiesels made from soapnut oil and

candlenut seed oil. These biodiesels were mixed in various ratios with diesel—B5, B20, B40, and B60—and all of the fuel blends were tested for combustion and emission characteristics. The results led to the following conclusions: the 10% candle nut and 90% soap nut biodiesel mixture produced the best test results in terms of CFPP and oxidation stability.

2.5 LITERATURE BASED ON THRUST

(Zehra Habib et al., 2010) studied a 30 KW gas turbine engine's performance and emissions characteristics were examined at various throttle levels while burning Jet A, soy methyl ester, canola methyl ester, reused rapeseed methyl ester, hoard fat biofuel, and their half (volume) mixes in Jet A. The utilization of biofuel prompted an expansion in thermal efficiency, a lessening in static thrust and thrust-specific fuel consumption. Thermal efficiencies of Jet A and the mixes were significantly lower than those of the pure biofuels. For all fuels, there were no appreciable variations in the engine exhaust gas and turbine inlet temperatures.

Radoslaw Przysowa et al., (2021) studied that the variations between the investigated mixes and mineral gasoline were so slight that the implications on engine operating characteristics were minor, according to a review of engine performance indicators. Therefore, their use posed no significant risk to the operation or fuel efficiency of aircraft. It may be deduced from the DGEN 380 turbofan's performance statistics that variations in relative thrust and fuel consumption during testing are frequently less than 1%.

A work by Yazan Altarazi et al., (2022) studied five different dual biodiesel blends B10-Jet, B30-Jet, B50-Jet, B70-Jet, and B90-Jet that were tested, with the results of Jet-A fuel serving as the standard. Compared to Jet-A gasoline, the B10-Jet blend showed greater fuel efficiency results. The specific fuel consumption (SFC) for B30-Jet and B50-Jet blends, in comparison, was comparable to that of Jet-A fuel. The least quantity of CO and CO₂ emissions came from the B10-Jet blend of Jet-A fuel. While B10-Jet fuel has a similar EINO_x value to Jet-A fuel, Jet-A fuel emits less NO_x than dual biodiesel fuels. As

a result, the physicochemical qualities of palm oil biodiesel were enhanced by combining it with *Thespesia populnea* methyl ester as fuel. As a result, the dual biodiesel blends performed better than the single biodiesel blends.

The performance and emission characteristics of a gas turbine engine, using ethanol/Jet A blends were studied by (C.J. Mendez., et al 2012). Due to their lower energy level, ethanol blends reduced the maximum operational RPM by 10,000–20,000 rpm compared to Jet A fuel. Since more fuel was being pumped into the combustion chamber as the engine RPM climbed, the temperature at the turbine inlet also rose. While the CO emission index was the same for all the fuels, the NO_x emission index drastically fell as the ethanol proportion in the mix increased. The E25 blend had the lowest overall pollution emissions while maintaining engine performance.

CHAPTER 3

MATERIALS AND METHOD

In this project report chapter 3 consist of materials and method used during the experimental work of this project. Methodology suggests the flow of the work that was conducted during the entire project. Soapnut and Candlenut oil where used as biofuel and were blended with diesel to prepare a unique biodiesel and was tested in a Jet engine to determine the thrust and smoke meter was used to determine the emission characteristics.

MATERIALS AND METHODOLOGY

The primary goal of this project is to find a substitution to Jet A fuel and find a better performing biodiesel using different non edible oil. Hence, from literature review we found two best seeds those are Candle nut and soapnut. Candlenut oil was extracted from candle nut seeds by a crushing and filtration procedure. A two-step co-solvent esterification technique was used to create the candle nut biodiesel. The candle nut biodiesel depicted poor oxidation stability, resulting in a high acid value and the formation of insoluble gums and dregs. The similar process is used to transesterify soapnut oil which is obtained from soapnut seeds. This oil has greater oxidation stability than candlenut biodiesel. Due to higher cold filter plugging point of candlenut biodiesel and higher oxidation stability of soapnut biodiesel, combining them will produce a new type of alternate fuel which will improve engine performance while emitting fewer pollutants than other fossil fuels.

After these biofuels are produced next step is to mix these two type of fuels in proportion of type I i.e. 80% Soapnut oil + 20% Candlenut oil and type II 80% Candlenut + 20% Soapnut oil. Once these types of biofuel are blended in proportion, B20 and B5 blends are mixed well using each type. The engine tests conducted to investigate the thrust produced showed performance that was at par with that of diesel. This new kind of biodiesel blend can prove to be an effective alternate fuel to conventional types. The emission tests conducted for

the blends of soapnut methyl ester and candlenut methyl ester have shown reduction in emissions of unburnt hydrocarbons, NO_x and increase in oxygen content.

3.1 PROJECT METHODOLOGY

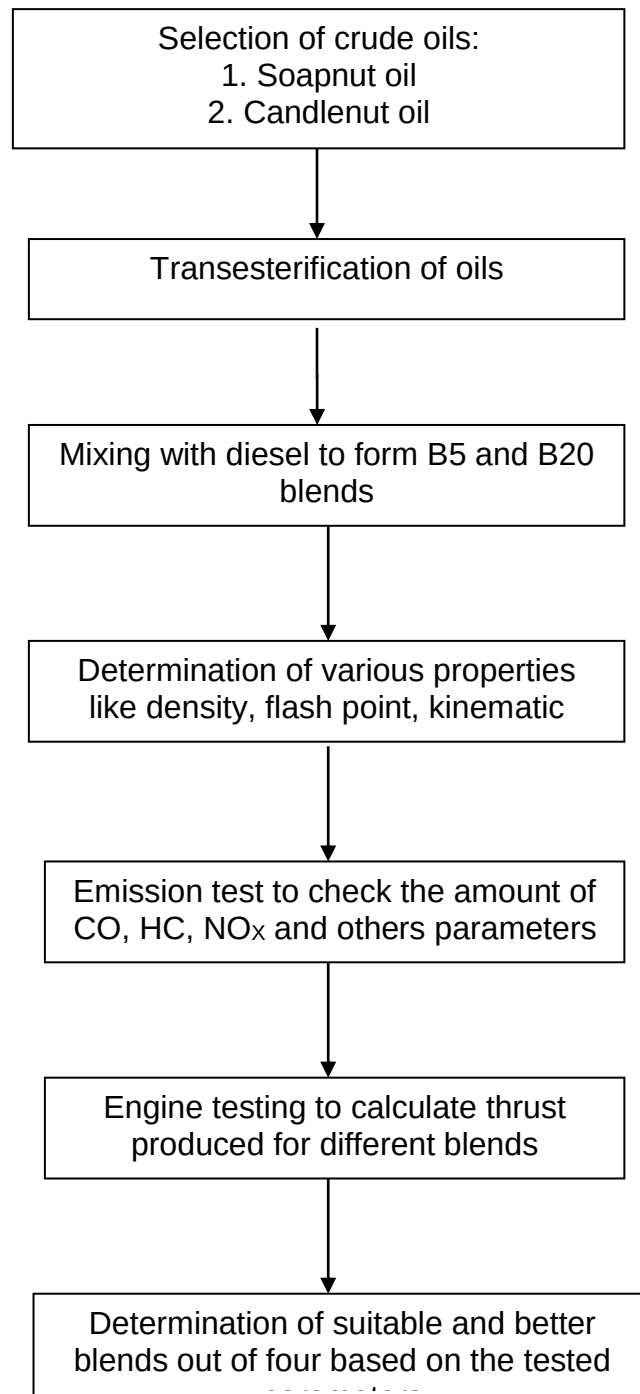


Figure 3.14: Flow Chart of Project Methodology

3.2 CANDLENUT & SOAPNUT PREPARATION METHODOLOGY

a) Preparation of candlenut biodiesel

In the initial process of making candlenut oil, the candlenut seeds were first dried. They were subsequently pressed, crushed and then squashed to get the raw oil out of the seeds. After the raw oil is acquired out of the seeds the oil is then well blended with dust oil. Subsequent to blending, the oil had been filtered through an oil filter to get clean raw oil. A two-step co-solvent esterification procedure was used to acquire the candlenut biodiesel. The Esterification procedure was carried out using acetonitrile as a co-solvent which helps reduce the Free Fatty Acids. As the underlying step, the free unsaturated fat from the candlenut oil was disposed in the first stage by employing acetonitrile in 10:3 ratios as a co-solvent. Initially 500 ml capacity three-neck round bottom flask was connected with a condenser, a thermometer, and a nitrogen gas flow pipe in the reaction flask fitted with a magnetic stirrer, the temperature of the water jacket was kept constant at 65 °C. Methyl alcohol was blended to sulphuric acid to 23:1 and was kept in the flask for 1 hour stirring the candlenut oil constantly. Then the oil obtained was refined and mixed well with aqueous sodium hydroxide (NaOH) to neutralize the content and then washing it with water and kept it under vacuum pressure to dry.

Following drying, we get crude CNO and proceed to the second phase of the transesterification process. In a 250 ml identical flask filled with water and held at 40 °C, the resulting cleaned and dehydrated candlenut oil was blended with acetone at a 20% concentration. The catalyst KOH was mixed in a 5:1 ratio with methyl alcohol and then added to the candlenut oil while stirring continually for one hour. The oil was then discharged into a separating funnel and left undisturbed for 45 minutes to separate the glycerol, methyl alcohol, and acetone.

At the lowered pressure strain, the top layer solution was processed to remove acetone and methyl alcohol. The consequent solution was neutralized with 5% aqueous phosphoric acid before being rinsed with water to achieve a pH of 7.0. The resulting solution was then distilled for 45 minutes at 80 °C under reduced pressure.



Figure 3.15: Candlenut Methyl Ester



Figure 3.16: Candlenuts, Kernels and Candlenut Oil

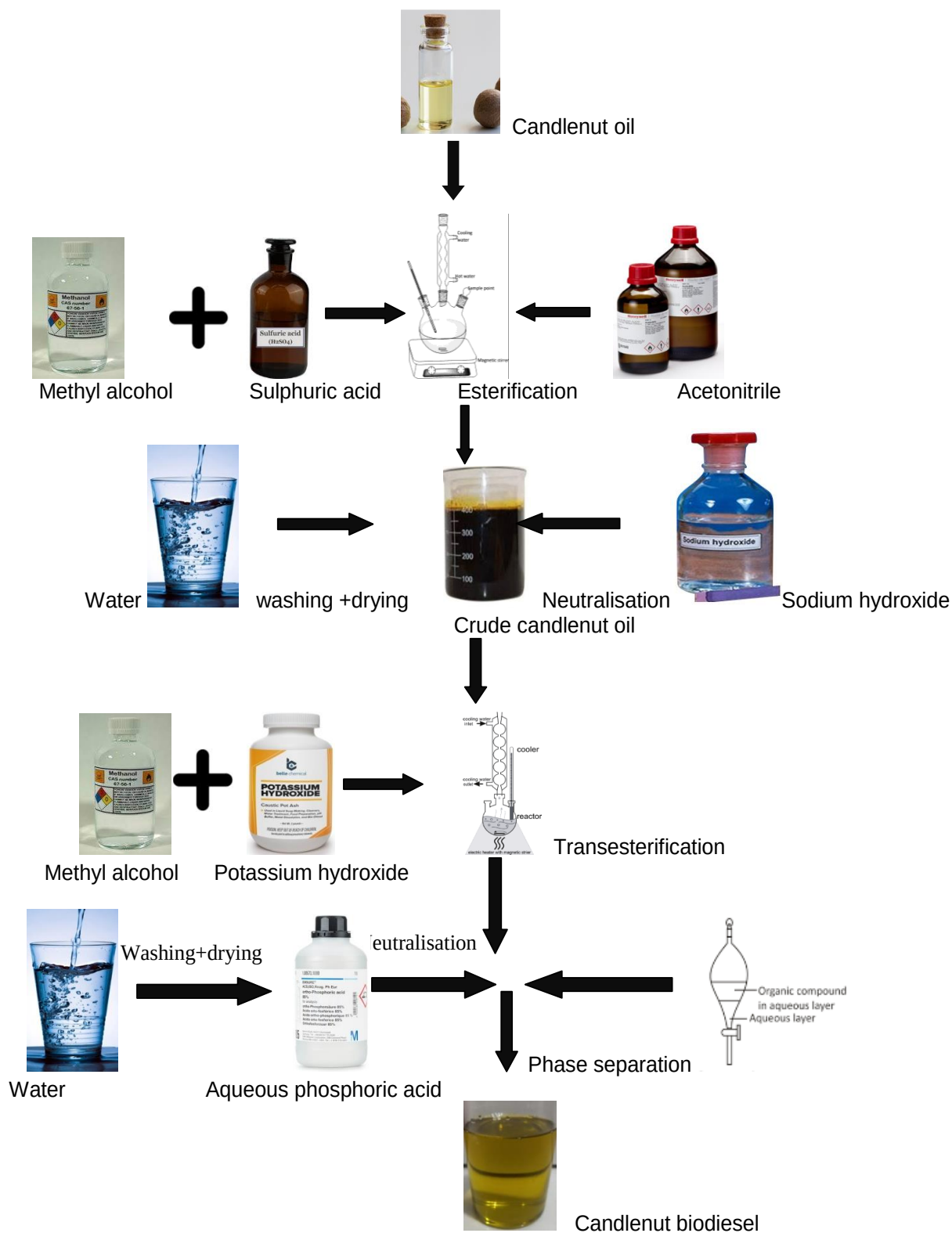


Figure 3.17: Transesterification of Candlenut Oil

b) Preparation of Soapnut biodiesel

Soapnut is the fruit of the soapnut tree, which grows in tropical and subtropical climates all over the world, including Asia, the Americas, and Europe. Hence, in order to manufacture Soapnut Oil from the seeds, we must first dry and mechanically crush the soap nut seeds, yielding raw soap nut oil. The oil obtained was filtered to remove residues, impurities such as dust, small particles etc.



Figure 3.18: Soapnut Methyl Ester

During 1 hour at 600 C, a mixture of 1 mL sulphuric acid and 40 mL methyl alcohol was forcefully mixed with 250 mL soap nut oil. Potassium hydroxide, which behaves as a catalyst, is well mixed in this methanolysis process, which is carried out in a Pyrex glass reactor including a water jacket. During the separation phase, it was permitted to settle for another 4 to 6 hours after one hour, resulting in the separation of glycerol and biodiesel. By opening the bottom knob, the glycerol was removed, and the remaining oil was rinsed with salt chloride until the methyl alcohol was extracted. Lastly, the clean soapnut biodiesel was cleaned with anhydrous magnesium sulphate and filtered. Soapnut biodiesel is the end outcome.

To create a combined biodiesel, candlenut oil and soap nut oil biodiesels were mixed in quantities of 20% to 80% and 80% to 20%, respectively. To attain the appropriate performance and emission levels, this biodiesel was blended with 95% and 80% diesel, respectively. The properties of the test samples were examined in line with the standards to obtain its fuel characteristics.

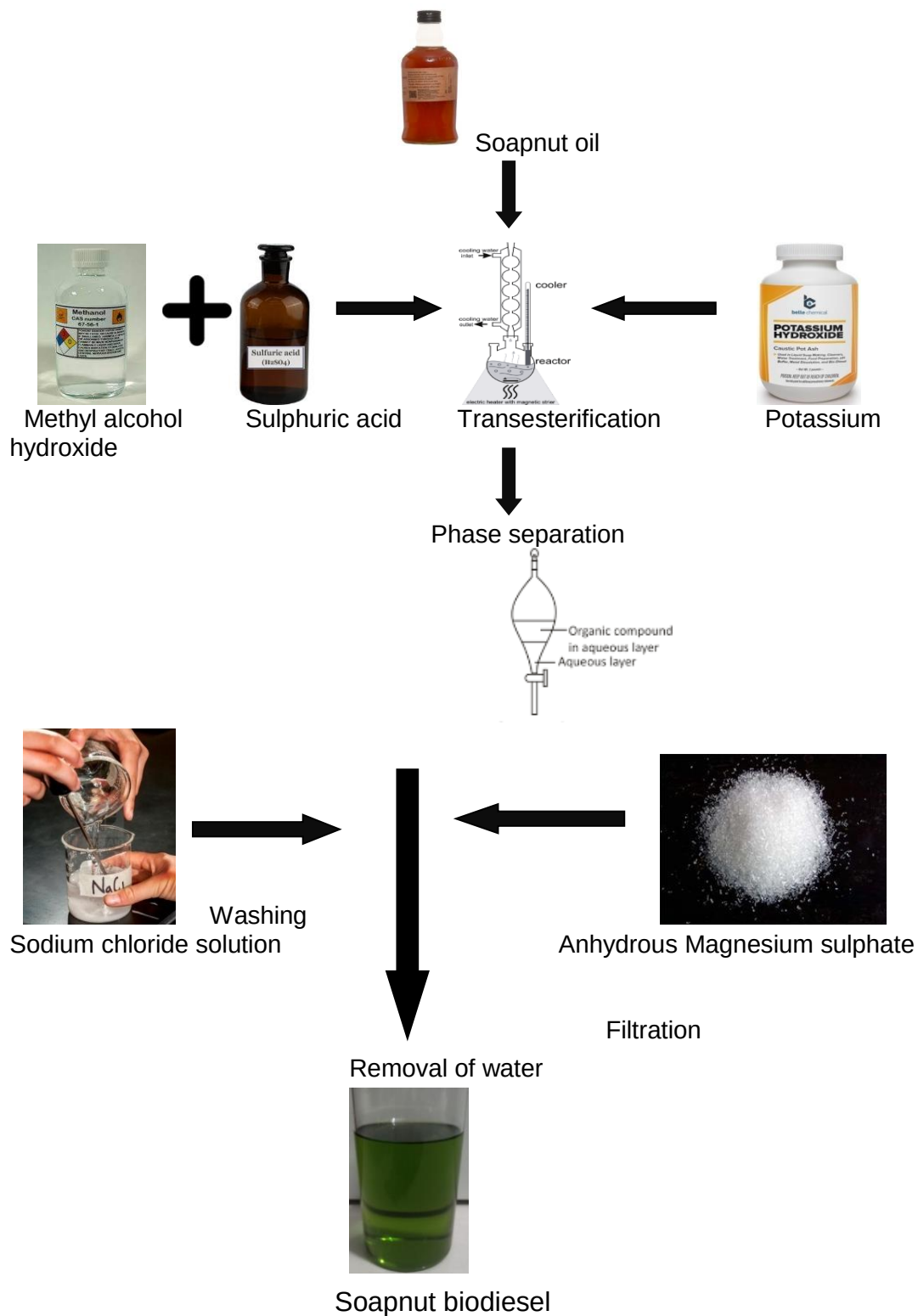


Figure 3.19: Preparation of Soapnut Biodiesel

3.3 PROPERTIES OF BIOFUEL

The test samples' parameters such as calorific value, kinematic viscosity, cold filter plugging point and oxidation stability were tested in accordance with the standards. The kinematic viscosity of the gasoline samples was determined using ASTM D445 standards. The gross calorific value of the fuel samples was determined using an ASTM D240 bomb calorimeter. The density of the fuel samples under consideration was tested in accordance with ASTM 5002 standards.

Table 3.1: Properties of Candlenut Oil Biodiesel

S.No	Parameters	Results
1	Density	0.876 g/cc
2	Kinematic Viscosity @ 40°C	2.21 cSt
3	Copper Corrosion strip @60°C	1 a
4	Flash point by PMCC method	125 °C
5	Fire point by PMCC method	133 °C
6	Cloud Point °C	3 °C
7	Pour point °C	-9 °C
8	Moisture Content	0.023 %
9	Acid Value	0.22 NaOH in mL/gram of oil
10	Calorific value	8018.006 Cal/g
11	Free fatty acid	0.22 %
12	Catalyst (NaOH) quantity	5 grams
13	Oil to methanol molar ratio	1:6
14	Temperature	60 °C
15	Reaction time	90 minutes
16	Yield	97.23 %
17	Cetane Number	34

ASTM D6371 standards were used to determine the cold filter plugging point of the samples. The Rancimat test instrument was used to obtain the oxidation stability of the samples in accordance with EN15751 requirements.

A two-step co-solvent approach for BDF synthesis from CNO was investigated in this paper. Initially, esterification of free fatty acids (FFAs) (0.22wt.%) contained in CNO was performed using acetonitrile (30 wt.%) as a co-solvent and H₂SO₄ as a catalyst wt.%. The Cetane number was 34, the cold filter plugging point was -8°C, the oxidation stability was roughly 1.8 hours, the flash point was 125 °C, the iodine value was 0.4 g, and the kinematic viscosity was 2.21 cSt at 40 °C. The fire point is 133°C, the pour point is -9°C, the cloud point is 3°C, the reaction time is up to 90 minutes, and the yield is around 967.23%. Moreover, the CNME's oxidation stability met the criteria of the biodiesel parameters.

Table 3.2: Properties of Soapnut oil Biodiesel

S.No	Parameters	Results
1	Density	0.856 g/cc
2	Kinematic Viscosity @ 40°C	2.18 cSt
3	Copper Corrosion strip @60°C	1 a
4	Flash point by PMCC method	180 °C
5	Fire point by PMCC method	193 °C
6	Cloud Point °C	7 °C
7	Pour point °C	-1 °C
8	Moisture Content	0.013 %
9	Acid Value	0.27 NaOH in mL/gram of oil
10	Calorific value	7163.18 Cal/g
11	Free fatty acid	0.39 %

12	Catalyst (NaOH) quantity	5 grams
13	Oil to methanol molar ratio	1:6
14	Temperature	60 °C
15	Reaction time	90 minutes
16	Yield	96.58 %
17	Cetane Number	58

. The viability of producing biodiesel from soapnut (*Sapindus mukorossi*) oil was explored in terms of fuel characteristics and blending capabilities with diesel. Soapnut oil methyl esters (SNME) demonstrated acceptable fuel characteristics, with the primary components being methyl oleate (55.2 wt.%), methyl eicosenoate (23.9 wt.%), and FAA (approximately 0.39%). The cetane number of the SNME was 58, the cold filter plugging point was 6 °C, the oxidation stability was 16.2 hours, the flash point was 180°C, the iodine value was 83.6 g I₂/100 g, the kinematic viscosity was 2.18 cSt at 40 °C, the fire point was 193°C, the pour point was -1°C, and the yield was approximately 96.58%. Moreover, the SNME's oxidation stability met the criteria of the biodiesel parameters. To explain the differences in the attributes of the SNME-diesel blends with the volumetric % of the SNME, linear correlations were created.

Table 3.3: Oxidation Stability and Cold Filter Plugging Point

Properties	Cold Filter Plugging Point (°C)	Oxidation Stability (HOURS)
Soapnut Oil	6	16.2
Candlenut Oil	-8	1.8
Type I (SN 80% + CN 20%)	-1	3.56
Type II (CN 80% + SN 20%)	-6	26.72
Type I (5%) + Diesel (95%)	-3	18.23
Type I (20%) + Diesel (80%)	-2	9.88
Type II (5%) + Diesel (95%)	-1	7.56
Type II (20%) + Diesel(80%)	-2	16.81

When compared to candle nut biofuel, soapnut biofuel has a better oxidation stability. Similarly, candle nut biodiesel has a higher cold filter plugging point than soap nut biodiesel, and this is determined by saturated fat. It was discovered that the CFPP and oxidation stability of mixed fuel soap nut and candle nut methyl ester were ideal for use. It was discovered that the oxidation stability of mixed fuel was higher than that of candle nut biodiesel. In comparison to soap nut biodiesel, the cold filter plugging point of mixed fuel was shown to be higher. The biodiesel blend was 5% (B5) and 20% diesel (B20).

3.4 MIXING OF TWO BIOFUELS

The mixing of biofuels was carried out as follows:

From the total quantity of soapnut oil and candlenut oil obtained, 80% soapnut methyl ester was mixed with 20% candlenut methyl ester, and this was categorized as type I. Type II was generated similarly by mixing 80% candlenut methyl ester and 20% soapnut methyl ester. Moreover, B20 was created by

combining 20% type I and II with 80% diesel, while B5 was created by combining 5% type I and II with 95% diesel.

Biofuel is regarded as the purest and most easily accessible fuel on the planet. Biofuels are made from biomass such as wood and straw, which is released by direct burning of dry materials and converted into a gaseous and liquid fuel. It may be used as a vehicle fuel in its pure form (B100), but it is most commonly employed as a diesel additive to minimize particulates, carbon monoxide, and hydrocarbon emissions from diesel-powered vehicle.

In the retail diesel fuel trade, biodiesel and conventional hydrocarbon-based diesel blends are most often supplied. Most of the globe uses the "B" factor to calculate the quantity of biodiesel in any fuel blend:

- 100% biodiesel is referred to as B100
- 20% biodiesel, 80% petrodiesel is labeled B20
- 7% biodiesel, 93% petrodiesel is labeled B7
- 5% biodiesel, 95% petrodiesel is labeled B5
- 2% biodiesel, 98% petrodiesel is labeled B2

Blends with 20% biodiesel or less can be used in diesel equipment with minimal or minor modifications, however some manufacturers will not extend warranty coverage if the equipment is harmed by these blends. The ASTM D7467 standard covers B6 through B20 mixes. Biodiesel can also be utilized in its pure form (B100), however specific engine modifications may be required to avoid maintenance and performance issues.

3.5 ENGINE SPECIFICATION

The jet engine used for calculating the thrust is indigenously manufactured by Mr. Khaled who has also been awarded in the Defence Expo, India 2022. The engine is named TS engine. It consists of four basic parts such as inlet, compressor, combustion chamber, turbine and nozzle.



Figure 3.20: Side View of TS Jet Engine

The turbofan has as its 'core' a compressor, combustor, and a turbine which drives the compressor. The test equipment is shown below. It also consists of combustion chamber which consist of hibernation tubes where the biodiesel is converted into gas and allows the primary, secondary and tertiary stage to conduct the combustion effectively. The engine test equipment consists of a Turbine size 66 mm. The centrifugal compressor size of the engine is 66 mm and is a Single Stage Centrifugal gas turbine jet engine. It is made up of Guide Vanes, which are permanent grooves found in turbines that help the flow of water, gas, or air around bends. Intake Guide Vanes (IGVs) provide air to the axial compressor inlet of a gas turbine. They reduce the possibility of undesired emissions by maintaining a suitable fuel-to-air ratio throughout a wide variety of load conditions. Guide Vanes guarantee that a fluid is passed evenly and smoothly as Impellers increase or reduce the flow of a substance through a system,



Figure 3.21: Front View of TS Jet Engine

Diffuser and a combustion chamber are also included. After the compressor, the diffuser is a critical component of the gas turbine combustor. Its principal role is to reduce the air flow provided by the compressor, promoting efficient combustion and avoiding high total pressure losses. Bearings are used in aviation engines to allow free rotation of shafts, discs, and airfoils, which compress air and extract power from a combustion cycle. Splines are used in aviation engines to transmit torque between shafts that are lined up throughout the engine's length. A jet engine turbine blade is an individual component of an aviation engine's turbine section. When rotating at high speeds, the turbine blades are subjected to the toughest environment in terms of pressure and temperature. The blades are in charge of extracting energy from the combustor's high temperature, high pressure gas. A k-type thermocouple was used to monitor the gas temperature of the exhaust discharge.



Figure 3.22: Back View of TS Jet Engine

.To decide its performance and emission qualities, the average value was processed from the obtained values. Readings were taken for various blends B5 and B20 under various combinations and load circumstances without any engine modifications. The emission parameters were measured using a gas analyzer and a smoke metre. The engine is originally started by combusting butane gas sprayed into the combustion chamber. Lubricant 2T oil is used for smooth operation and lubrication of components and bearings. A spring gauge is used to calculate the thrust generated by the engine's forward motion. To facilitate this, the engine is mounted on a table with movable frames.

3.6 Exhaust Gas Emission Measurements Devices

In this following chapter, the emission characteristics such as NO_x , CO, CO_2 , Smoke Opacity etc. has been found for different kinds of biodiesel blends and thrust and mass flow rate is measured for different blends of biodiesel respectively.



Figure 3.23: Exhaust Gas Emission Analyzer & Smoke Meter

The various contents of exhaust gas such as CO, CO₂, NO_x, HC, O₂ and smoke opacity were measured using the smoke meter. A sample of exhaust gas was taken from the test engine's exhaust pipe. The output data from the A/D card was analyzed using the AVL 615 Indimeter tool. An exhaust gas analyzer (AVL-444 DI GAS ANALYZER) assessed the test engine's HC, CO, and NO_x emissions. A chemical sensor that is attached adjacent to the oxygen sensor allows for the measurement of NO_x. A catalyst serves as the sensor for calculating NO_x concentration.

Exhaust gas sample from the test engine's exhaust pipe was obtained, passed through a filter, and then put into the NO_x analyzer. In this analysis, the test engine's smoke emission was also measured. A Bosch smoke metre of the opacity (AVL manufacture) type was used to monitor smoke output.

CHAPTER 4

RESULTS AND CONCLUSION

4.1 EMISSION CHARACTERISTICS

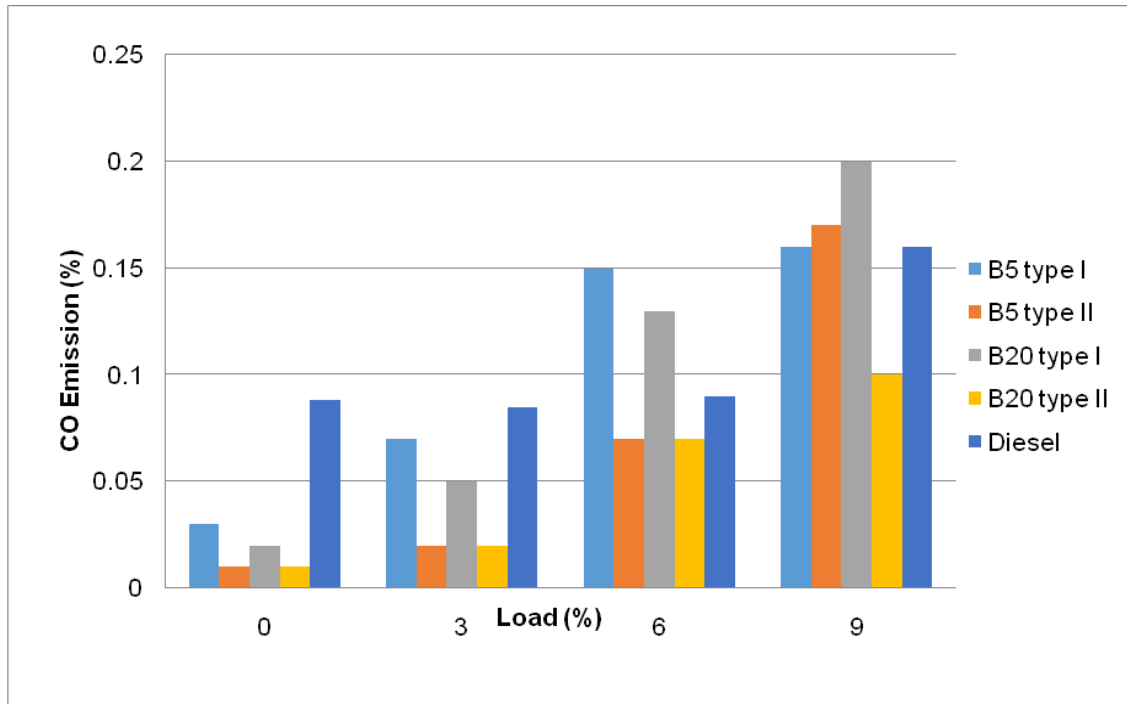


Figure 4.24: CO Emission v/s Load For Different Fuel Blends

Carbon Monoxide for B5 and B20 blend

The emissions were created by incomplete burning of carbon, which resulted in carbon monoxide. Type I biodiesel for B5 and B20 diesel blends emitted CO equivalent to 0.16% and 0.2% respectively. The above graph contrast the change in rate of carbon monoxide; all blends indicated lower amounts of CO when evaluated with diesel. Also, when the load rose, CO emissions climbed at higher levels, which is still a problem from an environmental perspective. For example, at 30% engine load, the Type II blend showed 0.02% CO, which is 325% lower than standard diesel. This amazing reduction in CO was observed in the type II blend whereas the type I blend has

214% reduction than standard diesel. As a result, hybrid fuel is the sensible choice for future engine power. In terms of breakdown, as the load increases to 60% the test fuels Type II for B5 and B20 reported 0.07, which is 28.57%, less than the standard diesel. At 90% load B5 blend give similar Carbon footprints to that of diesel but the type II blend for B20 shows 60% emission reduction than standard diesel whereas, type I blend has 20% increased carbon emission than standard diesel. The enhanced cetane number and the elevated amount of oxygenated biodiesel showcase the Carbon emission of biodiesel blends to a lower level than fossil diesel fuel.

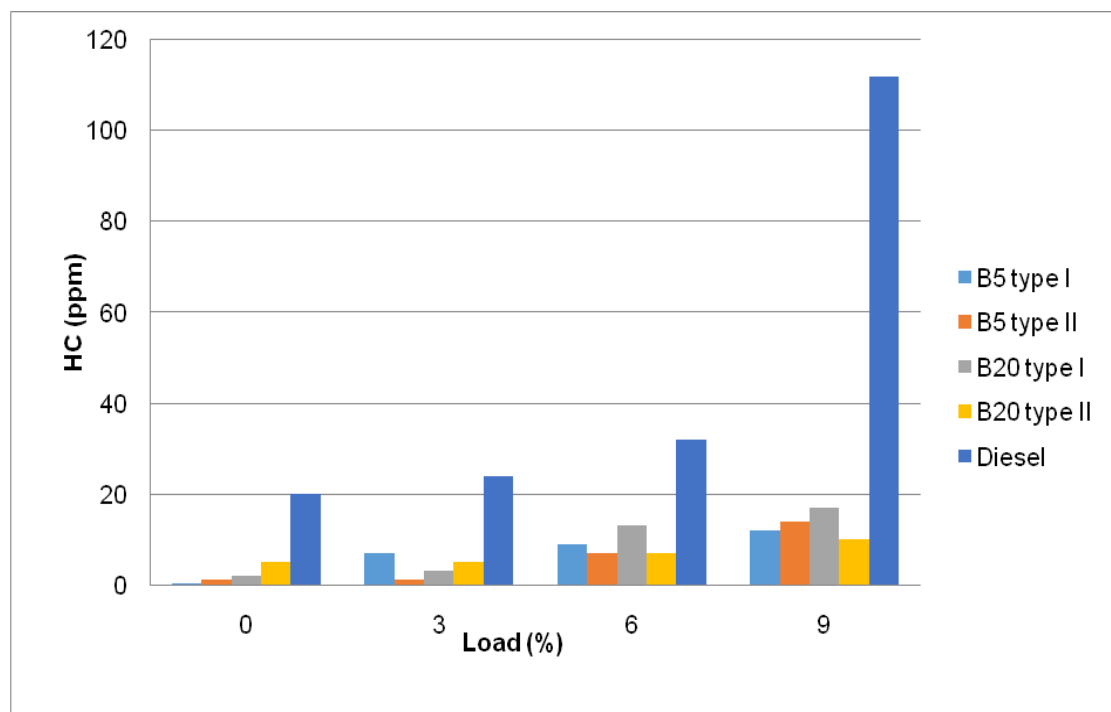


Figure 4.25: HC Emission v/s Load For Different Fuel Blends

Unburnt Hydrocarbon for B5 and B20 blend

Combustion of biodiesel alone provides over a 90% reduction in total unburned hydrocarbons (HC), and a 75–90% reduction in polycyclic aromatic hydrocarbons (PAHs). The hydrocarbon emissions for Type II biodiesel evaluated for the B5 and B20 were determined to be 10ppm and 14 ppm respectively, as shown in above graph. Due to imperfect burning of fuel the

unburned hydrocarbon emission were seen. Due to high concentration of oxygen in biodiesel blends, hydrocarbon emissions are reduced. The test fuels Type I B5 and Type I B20, on the other hand, reported 12 ppm and 17 ppm respectively, which is 833% and 558% less than standard diesel. In the case of the type II B5 and Type II B20, HC recorded 1020% and 700%, lower Hydrocarbon emissions as compared to standard diesel.

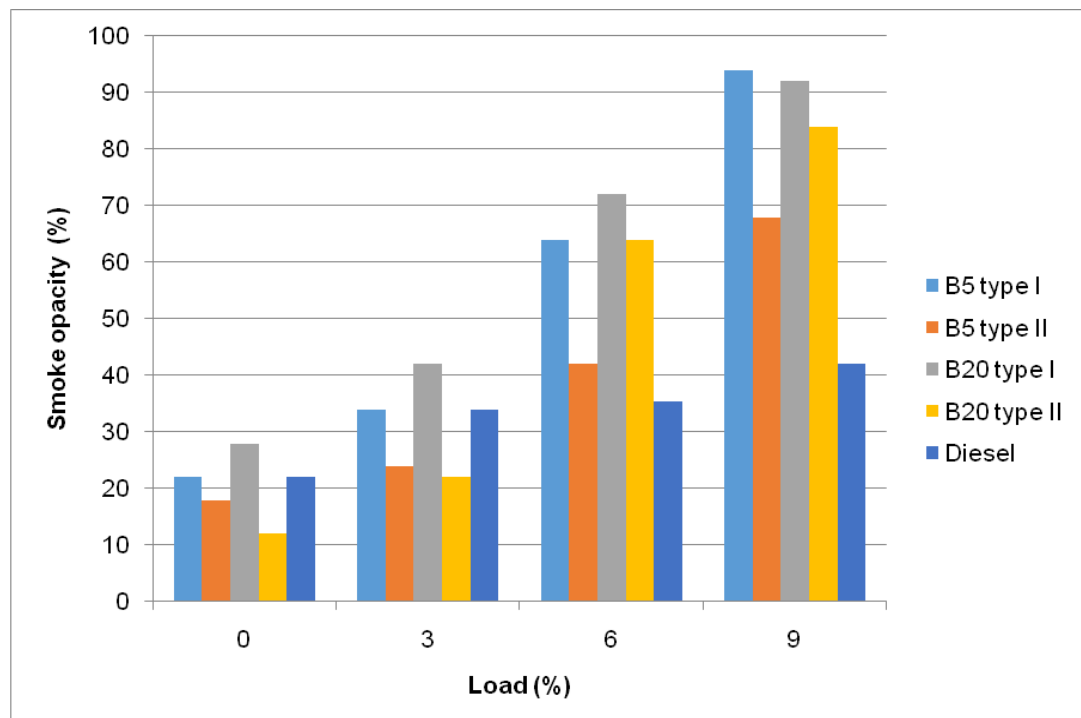


Figure 4.26: Smoke Opacity Emission v/s Load For Different Fuel Blends

Smoke Opacity for B5 and B20 blend

At maximum load, the smoke intensity for Type I mixtures examined for the B5 and B20 was 94% and 92%, respectively. The percentage decline in typical diesel smoke opacity is 55.32% and 54.35%, respectively. The smoke emission was found to be lower for the 80% candle nut and 20% soap nut biodiesel mixture compared to other mixes due to the lower unburnt hydrocarbon release, B5, and B20, which are 38.42% and 50%, respectively. The results showed that using biodiesel reduces smoke opacity while increasing fuel consumption by up to 7.38% when compared to petrodiesel. Exhaust emissions,

such as CO and HC, were reduced when biodiesel was used in fuels, owing to the impact of full combustion of the oxygen in biodiesel.

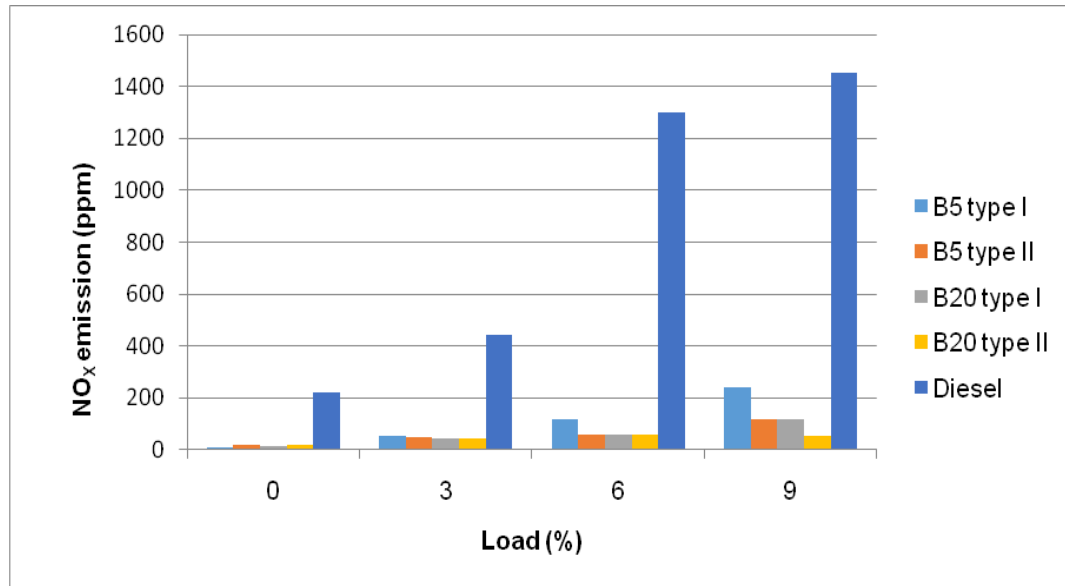


Figure 4.27: NO_x Emission v/s Load For Different Fuel Blends

Emission of Nitrogen for B5 and B20 blend

Since biodiesel has fewer particle emissions, it has a decreased capacity to dissipate heat, resulting in greater temperatures and, as a result, lower NO_x emissions. In reality, the most important characteristic that causes an increase in in-cylinder temperature is NO_x emissions are being reduced. The oxides of nitrogen emissions for type I biodiesel were determined to be 240 ppm and 120 ppm for the B5 and B20, respectively. There is a substantial drop in emission percentages ranging between 525% and 1150%. Nitrogen test findings performed well when compared to fossil fuel. The test fuels type II, B5, and B20 showed 120 and 570 ppm, which is 1150% and 2677.78% less than regular diesel, respectively. At peak load, type I B5 had a slightly greater amount of nitrogen than the other mixes. Nonetheless, there was reduced nitrogen emission at both the starting and peak loads.

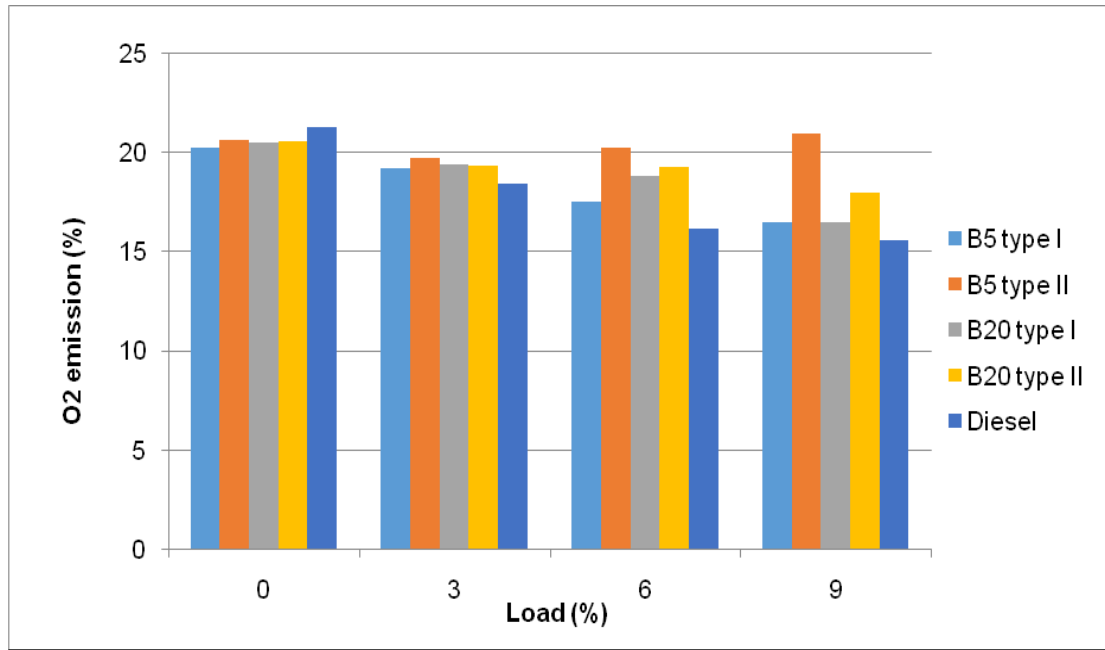


Figure 4.28: O₂ Emission v/s Load For Different Fuel Blends

Oxygen for B5 and B20 blend

The oxygen content in biodiesel is about 10 to 12%. Biodiesel is an oxygenated fuel and contains about 11% oxygen by weight. The oxygen content of biodiesel ranges between 9 wt.% to 12 %wt. The oxygen content helps to reduce of particulate matter, CO, UHC and provided better combustion process. The type I blend for B5 and B20 is similar that is 16.5% which is 6.5% more than the standard diesel. During 30% load the oxygen level of diesel is more than the other blended biofuel. But as the load increases the oxygen level also increases gradually as shown in graph above. The biodiesel in type II having B5 and B20 blend has resulted in 35.48% and 16.13% respectively, increase in amount of oxygen than standard diesel emission. This is further corroborated by the higher oxygen content of biodiesel as compared to diesel.

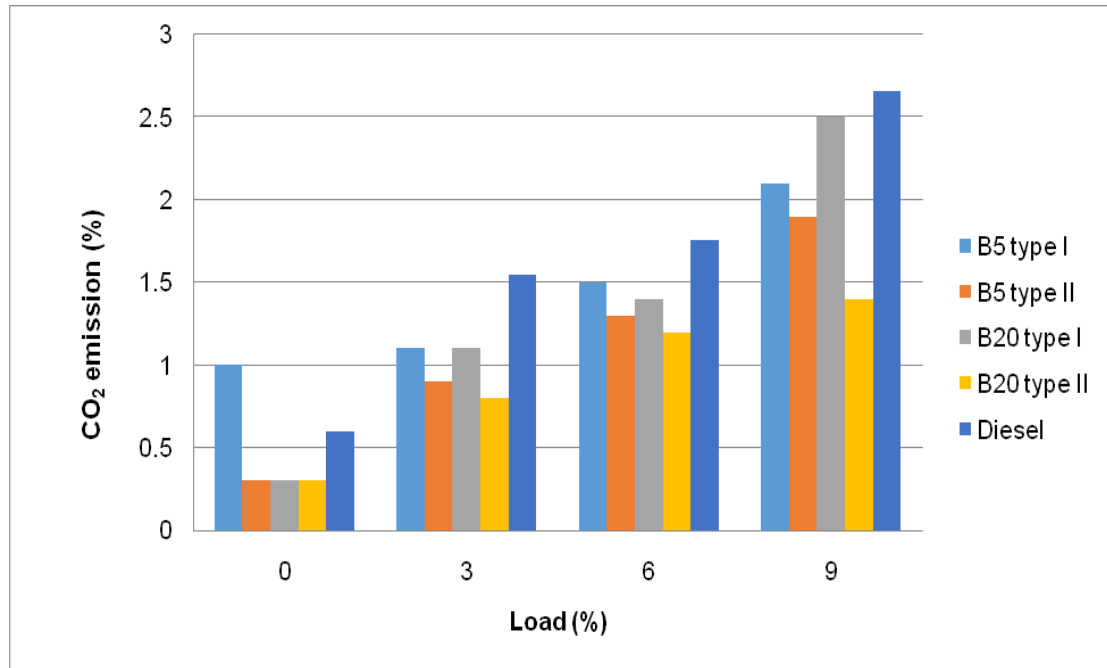


Figure 4.29: CO₂ Emission v/s Load For Different Fuel Blends

Emission of Carbon Dioxide for B5 and B20 blend

Given the presence of oxygen molecules in biodiesel, especially in the methyl or ethyl ester, which help in full combustion, CO₂ emissions from biodiesel combustion in diesel engines are 40 to 50% lower than those from ordinary diesel combustion. The emission for Carbon Dioxide for type I B5 and B20 was 26.67% and 6.4% respectively which is lower than a standard diesel emission. Whereas, the type II biofuel blend has lowest percentage of emission for B5 and B20 which is about 40% and 90% respectively. As shown in graph above, Carbon dioxide is emitted less in Type II Biofuel blend as compared to type I and standard diesel.

4.2 ENGINE PERFORMANCE CHARACTERISTIC

It was observed that the CFPP and oxidation stability of the blended fuel made from soap nuts and candle nuts were ideal and suitable for operating the engine without modification. It was shown that blended fuel has superior oxidation stability than candle nut biodiesel. When compared to soapnut biodiesel, the cold filter plugging point of blended fuel was found to be higher.

When compared to Candlenut biodiesel, the oxidation stability of blended fuel was found to be other way around. The mixed biodiesel was blended with diesel in the following proportions: 5% (B5) and 20% (B20) and the performance characteristics such as thrust for varying voltage, Mass flow rate for different fuel blend and emission-quality were assessed by passing through the Jet engine.

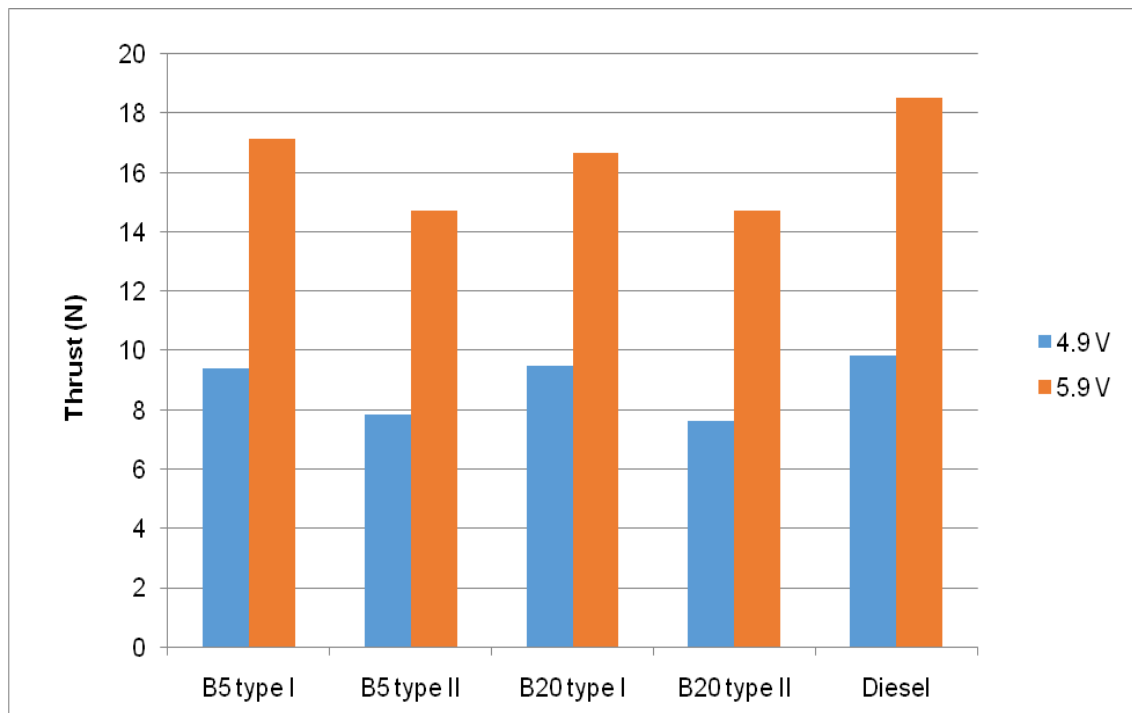


Figure 4.30: Thrust for Different Fuel Blends at varying Voltages

Table 4.4: Thrust produced on various Biofuel Blends

Supplied to fuel pump*	Pure Diesel	B5 type I Type I (5%) + DIESEL (95%)	B5 type II Type II (5%) + DIESEL (95%)	B20 type I Type I (20%) + DIESEL (80%)	B20 type II Type II (20%) + DIESEL (80%)	Kerosene
Voltage (V)	Thrust (N)	Thrust (N)	Thrust (N)	Thrust (N)	Thrust (N)	Thrust (N)
4.9	9.81	9.417	7.848	9.466	7.612	15.794
5.9	18.54	17.167	14.715	16.677	14.715	23.298

*voltage indicates the rate of fuel supplied to engine

Type I: 20% candlenut oil + 80% soapnut oil

Type II: 80% candlenut oil + 20% soapnut oil

A cylindrical type of combustion chamber is used in turbojet engines. Inside and outside walls that is coaxial with the driving shaft that connects the turbine and the compressor make up the combustion-chamber annulus. The combustion process is enhanced and its potential for oxidation is reduced by the oxygen content of biodiesel. Thrust is a driving force or a push force produced by an aircraft power plant. The thrust produced for various blends of biodiesel were tested in TS Engine and results are shown in fig 6 and are as follows at 4.9 Volt the B5 and B20 Type I has shown good amount of thrust with respect to Pure diesel. As the voltage increases at 5.9 voltage the same type has shown good amount of thrust produced.

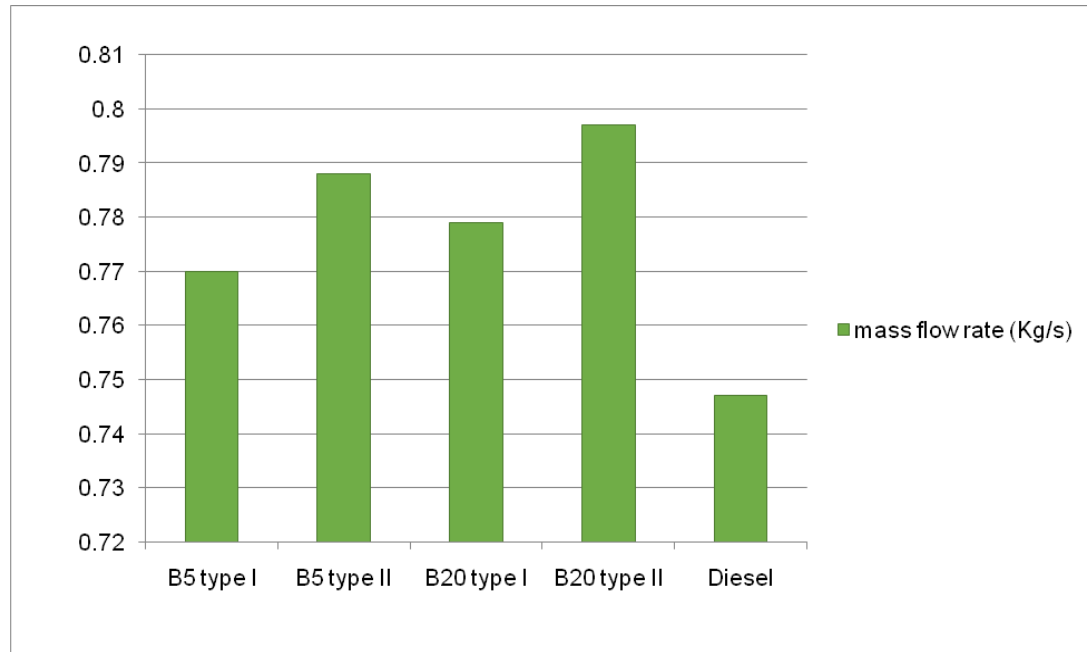


Figure 4.31: Biofuel Blend v/s Mass Flow Rate

Table 4.5: Engine Run Time and Mass Flow Rate of Various Blends

Fuel type (900 ml)	Mass flow rate (kg/s)	Engine run time
Pure diesel	0.747	6 minutes 45 seconds
B5 type I	0.770	6 minutes 49 seconds
B5 type II	0.788	6 minutes 34 seconds
B20 type I	0.779	6 minutes 28 seconds
B20 type II	0.797	6 minutes 48 seconds
Kerosene	0.738	5 minutes 14 seconds

The mass flow rate is the mass of a liquid substance passing per unit time. In other words, the mass flow rate is defined as the rate of movement of liquid which passes through a unit area. The mass flow is directly dependent on the density, velocity of the liquid, and area of cross-section. The mass flow rate is better than the fossil diesel, B5 type I and B20 type II has shown good mass flow rate compared to fossil diesel and for other blends it is comparatively point seconds lower but more less equal.

CHAPTER 5

5.1 CONCLUSION

The soap nut methyl ester and candle nut methyl ester were combined at a certain proportion as Type I 20% candle nut and 80% soap nut biodiesel mixture (CN20 + 80SN) and Type II 80% candle nut and 20% soap nut biodiesel (CN80 + 20SN). These biodiesels were mixed with diesel in B5 and B20 proportions, and all fuel blends were evaluated for thrust and emission properties, yielding the below subsequent results:

- Throughout the test, the blended fuel of Type II 80% Candle nut and 20% Soap nut biodiesel yielded the best results in CFPP and oxidation stability.
- Type I blend B5 and B20 consisting 20% candle nut and 80% soap nut biodiesel blend (CN20 + 80SN) reported equal amount of thrust when compared to fossil diesel.
- Type II blend has shown comparatively lower amount of thrust when compared to Type I.
- The mass flow rate of B5 Type I and B20 Type II has reported comparatively higher than fossil diesel.
- The high amount of oxygen present in biodiesel enriched the biodiesel resulting in a oxygenated biodiesel and high ignition temperature impact which discharged carbon monoxide emission, hydrocarbon discharge, and smoke thickness of biodiesel to a lesser significant than any remaining fossil diesel fuel.
- The increased level of oxygen rich biodiesel impacts nitrogen discharges of biodiesel to a more prominent level than any remaining fossil diesel fuel.

5.2 FUTURE SCOPE

Whenever done appropriately, biofuels are one of a few choices for diminishing oil reliance and fossil fuel byproducts that add to an unnatural weather change. These days, the rich notable biofuels are ethanol from sugarcane and corn (30 billion gallons each year) and biomass-based diesel from vegetable oils and creature fats (counting methyl ester biodiesel and sustainable diesel) (10 billion gallon each year). The contention over food versus fuel drove the business to investigate for substitute biomass sources, like wood, straw, green growth, and *Jatropha*. Various troubles lay ahead to end and converse humankind's harm to Nature, yet society can't just lessen its energy utilization. Subsequently, it should keep on utilizing existing energy sources all the more successfully while putting resources into sustainable, carbon-impartial energy sources.

For decades, biodiesel was primarily based on the transformation of vegetable oils to methyl esters. This is sometimes referred to as first-generation biodiesel assistance. Leftover cooking oils, animal fats, and vegetable oil refinery byproducts such as acid oils and fatty acid distillates are in high demand today, although these so-called second-generation biodiesels account for just a small portion of total production.

The recent anti-palm oil and anti-soybean campaigns launched by various consumer and environmentalist groups have had an impact on the biodiesel industry, particularly in Europe. Nonetheless, in Asia and Latin America, massive original biodiesel facilities capable of producing up to 1,500 tonnes of biodiesel per day are still being developed to service the local market as a result of legal mandates. As of September, for example, in Indonesia, B20 (and B30 in 2020) blends are required in the middle of efforts to reduce shortages in the country's economy by saving billions of dollars in petrol diesel imports. The policy also supports the region's growing palm oil business, which is under fire globally due to deforestation and unnatural weather change.

In any case, there is likewise a reasonable shift to squander oils and fats in these districts. Palm handling produces many side streams with no food esteem,

for example, palm unsaturated fat distillates, high unsaturated fats rough palm oil and palm ooze oil, which are being changed over into biodiesel. With endeavors to increment palm oil's food quality and wellbeing, new guidelines are before long expected, which will bring about more nonfood palm oil. Around 10 to 15 percent of all rough palm oil might fall into this classification. Such second rate feedstock's are great for biodiesel and ought to be advanced as needs be.

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