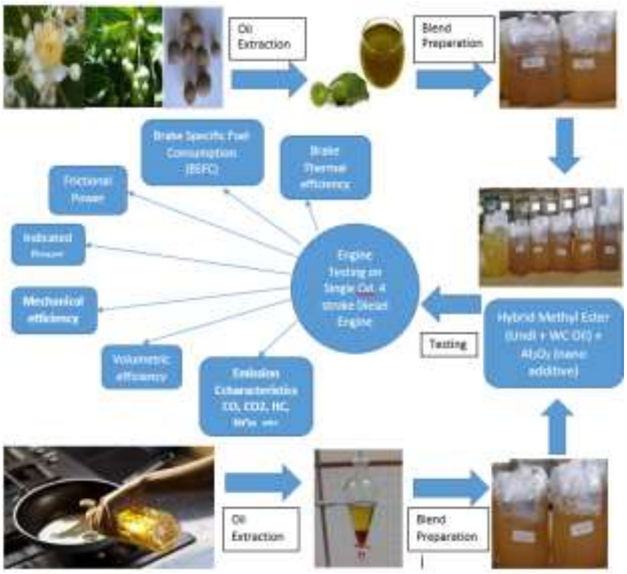
AN INVESTIGATION OF PERFORMANCE & EMISSION PROPERTIES ON DIESEL ENGINE POWERED BY HYBRID METHYL ESTER (WCO + CALOPHYLLUM INOPHYLLUM) WITH NANO ADDITIVES

Niraj B Dole[a*], Dr. Rahul B Barjibhe[b],

[a]Research Scholar, SSGBCOE&T Bhusawal, KBCNMU Jalgaon,425201,
Maharashtra, India.
[b]Research Guide, SSGBCOE&T Bhusawal, KBCNMU Jalgaon,425201,
Maharashtra, India.
Corresponding author mail id: ndraj290@gmail.com,

Abstract: *As the years are passing continuously the human being are facing the stringent problem of fossil fuel. Human are also suffering with the problem of emissions that is happening due to the use of petroleum-based fuels. So, it becomes the prime requirement of human to find the such a source of energy that can replace the diesel fuel which should be renewable in nature. In this study a hybrid methyl ester of Calophyllum inophyllum and Waste cooking oil is considered with addition of nano additive* Al_2O_3*. The role of additive is to boost up the performance parameters of fuel. For the testing of this hybrid methyl ester the 1C 4S diesel engine is consider with CR of 18. The blends are considered as B20F2, B20F4, B20F6, B20F8, B20F10. The readings are taken in variation of load 0kg, 3kg, 6kg, 9kg, 12kg. The result and discussion indicate that the hybrid methyl ester of B20F8 of Undi+WCO have good result like or more than that of diesel fuel. So proudly it can be said that in future if land area of biodiesel increases then it can replace the diesel fuel in future.*

Graphical Abstract:



Keywords: *Hybrid Biofuel, Undi, WCO, Vibration, ANN*

---

1. INTRODUCTION

The steady growth in the pace of use of fossil fuels has made the depletion of these conventional fuel supplies a foregone conclusion in the near future. According to the World Health Organisation (WHO), an estimated 7 million people worldwide die each year as a result of exposure to ambient and home air pollution. It also demonstrates that 9 out of 10 individuals breathe air with significant levels of pollution. Polluted air contains tiny particles that penetrate deep into the lungs and cardiovascular system, causing ailments such as heart disease, lung cancer, chronic obstructive pulmonary disease, and respiratory infections such as pneumonia. In their hunt for an alternative and sustainable energy source, scientists have developed a number of solutions, one of which is biodiesel diesel mixes as alternative fuels, which has gained the attention of many researchers. This is because scientists have discovered that the qualities of biodiesel made from vegetable oils are extremely similar to commercial diesel, giving it a hopeful future as an alternative fuel for diesel engines. In the near future, biodiesel has the potential to replace petroleum diesel. India is now one of the top 10 oil-consuming countries in the world. In the current fiscal year, India's oil import bill is expected to rise to 87.7 billion dollars. In 2016-17, India imported 213.93 million tones (MT) of crude oil for 70.196 billion dollars, or Rs 4.7 lakh crore. According to the most recent statistics from the energy ministry's Petroleum Planning and Analysis Cell (PPAC), imports for 2017-18 are estimated at 219.15 MT for 87.725 billion dollars or Rs 5.65 lakh crore. As a result, biofuels such as alcohol, vegetable oils, biomass, biogas, biodiesels, and so on are becoming more essential in developing nations such as India due to their renewable and ecologically benign characteristics. Some of these fuels may be used directly, while others must be modified before being utilised as a replacement for conventional fuel.[1][2]

2. LITERATURE REVIEW

Biofuel might replace fossil fuel. The easiest method to make biodiesel in Malaysia is by mixing palm oil with CDF. Biodiesel performance must be shown to be superior than CDF as fuel. This study examined combustor temperature profiles. Biodiesel gas emission analysis studies exhaust pollution reduction. This research will establish the ideal mix for performance and emission compared to CDF and examine the flame pattern. Biodiesel blends of B5 perform better at stoichiometric mixing and have fewer emissions than CDF.[3] Renewable biodiesel might replace fossil diesel in diesel engines. Biodiesel manufacturing is being carefully considered using non-edible feedstock to avoid food issues. Free fatty acids in crude oils from Rattanjot, Undi, and Kapok tree surpass 2%. Therefore, preliminary acid catalysed esterification is necessary for free fatty acid reduction. High methyl ester yields (98.23%, 98.53%, and 97.72%) and low acid values (0.39 mg KOH/g, 0.45 mg KOH/g, and 0.40 mg KOH/g) were produced by combining the oils of Jatropha curcas, Calophyllum inophyllum, and Ceiba pentandra at a 9:1 M ratio (methanol to oil). In this study, two-stage esterification and transesterification enhanced the properties of biodiesel. In terms of kinematic viscosity, density, flash point, and calorific value, biodiesel complied with ASTM standards.[4]

Base-catalyzed transesterification produced methyl ester from undi L. oil. Standard techniques established the characteristics of raw undi L. oil and its methyl ester. The specific gravity and kinematic viscosity, GCV, Flash point, Fire point, Acid value, Free fatty acid content and Saponification value for raw Undi oil were observed.[5][6] Undi oil contains 60–70% biodiesel.Biodiesel manufacture begins with oil extraction. In-situ transesterification directly converts Undi seed smash into biodiesel using fatty acid methyl and ethyl ester composition. The single-step procedure is eco-friendly since hexane-like solvents were not employed for oil extraction. GCMS examined biodiesel components.[7] This study uses a hydrodynamic cavitation reactor to make biodiesel from leftover frying oil and purify FAME. Under optimised process conditions, the conversion was 93.86 mol%. In 20 min, conversion reached 93.6 percent, compared to 88.5% in 1 hour in stirred tank reactor. After transesterification, the reaction mixture included fewer intermediate diglycerides and monoglycerides. It separates methyl ester and glycerol layers in 1 h without difficulty. A little quantity of KOH catalyst required to complete reaction decreases KOH and soap in ester layer, which helps generate a less stable emulsion during water washing. At 70 °C, full separation occurred in 3 h. Thus, lowering separation and purifying time increases manufacturing capacity, according to this research.[8] Biodiesel is a renewable diesel fuel manufactured using vegetable oil and animals fat-derived fatty acid esters of methyl. This work reveals how to make nanocrystalline potassium ion impregnated calcium oxide as a solid catalyst for waste cottonseed oil transesterification with methanol. 3.5 wt% potash in CaO support catalyses best. The same catalyst transesterified cheaper waste cotton seed oil with 10.26 wt% humidity and 4.35 wt% fatty acids that were free. Three catalysts were reused. Few biodiesel parameters fulfil EN 14214 standards. [9]

A laboratory reactor transesterified waste cooking oils from Ho Chi Minh City, Vietnam, with methanol using alkali. Methanol/waste cooking oil ratio, potassium hydroxide concentration, and temperature affected biodiesel conversion. Biodiesel yielded 88–90% at 7:1–8:1 methanol/oil ratios, 30–50 C temperatures, and 0.75 wt% KOH. Biodiesel and diesel blends were characterised for their physical features as diesel substitutes. Biodiesel has a greater but narrower boiling range than diesel. Carbon residue reached 4%. Blends containing biodiesel below 30 vol% have physical parameters within EN14214, indicating that they may be utilised in engines without considerable modification.[10] Transesterified biodiesel from virgin vegetable oil costs more than diesel fuel, and batch reactors are expensive. Waste cooking oil and a modified blender were used as feedstock and reactor to save costs. Diesel fuel was synthesised from laboratory-scale methyl ester of WCO (MEWCO). KOH catalysed the transesterification of WCO with methanol using 100g WCO, 22.0g methanol, 1.0% KOH, 60oC, and 60 minutes. Results were averaged after replication. Classic reaction yielded 96.6 0.45% WCOME. WCOME met ASTM D6751 and EN 14214 biodiesel criteria. The fuel characteristics were similar to previous waste cooking oil methyl ester developed by other researchers using conventional reactors. The blender configured as a reactor may produce biodiesel from restaurant waste cooking oil at home.[11] Biodiesel requires used vegetable oil. Kolkata fritter sellers have donated discarded vegetable oil for biodiesel production. Oil-to-alcohol ratio, catalyst concentration, temperature, stirring rate, and reaction time impact transesterification. The technique was optimised to generate 94% biodiesel. Density, flash point, calorific value, and viscosity were evaluated for biodiesel.[12]

Transesterification of restaurant cooking oil produced neat biodiesel, which was subsequently blended with diesel. Blending ratio and compression ratio have been studied for diesel engine performance. When the engine ran on B10, B20, B30, and B50 blends and B0 diesel fuel, as well as compression ratios of 14, 16, and 18, emission and combustion parameters were examined. Compression ratio boosts engine torque for all mixes. At all compression ratios, higher blends have greater bsfc as biodiesel % rises. B10, B20, B30, and B50 brake thermal efficiency increased 18.39%, 27.48%, 18.5%, and 19.82% when compression ratio was changed from 14 to 18. When compression ratio increased from 14 to 18, CO2 emission rose 14.28%, HC emission decreased 52%, CO emission decreased 37.5%, and NOx emission climbed 36.84%. Biodiesel has a reduced igniting delay than diesel despite its increased viscosity and volatility. Compression ratio from 14 to 18 reduced delay duration by 13.95% on average. This research found that biodiesel's compression ratio benefitted more than diesel's.[13] This work analyses diesel engine emissions of CO, CO2, and NOx and technical performance related to consumption, power, and torque in a laboratory test rig to provide an environmental assessment. Vegetable cooking oil into biodiesel fuel. This study evaluates the best biodiesel production method by analyzing its unique characteristics and controlling physical environmental variables that may improve engine performance when blended with commercial diesel. Cooking oil is abundant and has no specified purpose, making it a valuable raw source for biodiesel manufacturing. The decrease of CO and CO2 emissions from combustion processes was noteworthy. [14]

Polanga Biodiesel has examined the combustion/performance/emissions of a (PBD)-fueled one-cylinder diesel engine using Al_2O_3 nano--additives at 25 and 50 part per million. The findings were compared to baseline diesel fuel at 25%/ 50%/75% and 100% engine loads in an agriculture-based single-cylinder diesel engine with 17.5 CR at 1500 rpm. Magnetic stirrer and ultrasonicater combined Al2O3 nano--additives with PBD. Due to their greater surface area-to-volume ratio, nanoparticles in PBD enhanced base fuel combustion and emission. Al2O3 nanoparticles also increased brake thermal efficiency (BTE) by 6.58% and decreased BSFC by 7.38%. Fuel-borne additives in PBD enhanced combustion efficiency, reducing HC, CO, NOx, and smoke opacity. PBD + 25 part per million Al2O3 had the lowest ignition delay (ID) whereas PBD + 50 part per million had the largest mass fraction burned (MFB). PBD + 25 ppm Al2O3 had the lowest particle size diameter (PSD) across engine load situations. In general, PBD + 50 part per million Al2O3 nano additions increase combustion and reduce emissions.[15] Diesel fuel using nanoparticles may burn cleaner and minimise pollutant emissions. Researchers examined numerous nanomaterial additives. This research examines diesel fuel with nano-Al2O3 and nano-TiO2. Iraqi fuel included 25–150 ppm nanoparticles. Nanomaterials greatly boosted ignition and cylinder pressure. Nano-TiO2 and nano-Al2O3 boosted traditional diesel brake thermal efficiency from 18.9% to 24.25% and 20.45%, respectively. 25 ppm nano-Al2O3 and nano-TiO2 boosted the cylinder's maximum pressure to 63.2 and 60.4 bar, respectively, under total load circumstances. [16]

Alternative fuel research was driven by rising energy needs, fossil fuel depletion, fuel usage, and toxic pollutants. Acid esterification and trans-esterification of Jatropha oil produced biodiesel. Mixing diesel and biodiesel oils yielded 20% jatropha biodiesel. CNTs, TiO2, and Al2O3 improve fuel properties. These additives were mixed with biodiesel at 25, 50, and 100 ppm. This article evaluates the performance and exhaust emissions of a diesel engine using Jatropha biodiesel mix and nano additives. A single-cylinder diesel engine was fitted with an experimental test setup to assess performance and emissions at different loads. The biodiesel mixture with nano Al2O3 as J20Al100 demonstrated a 6.5% increase in thermal efficiency. When compared to all fuels, J20C50 jatropha biodiesel with CNTs reduced CO and NOx emissions by 35 and 52%, respectively. When compared to alternative fuels, the J20T25 jatropha biodiesel blend with TiO2 reduced HC and smoke emissions by 22 and 50%, respectively. In terms of engine performance and emissions, jatropha biodiesel with nanoparticles (J20Al100/J20T25/andJ20C50) fared better than the other fuels.

.[17] Energy demand, fossil fuel depletion, fuel use, and harmful pollutants drove alternative fuel research. Jatropha oil acid esterification and trans-esterification created biodiesel. Diesel and biodiesel together produced 20% jatropha biodiesel. CNTs, TiO2, and Al2O3 enhance fuel. 25, 50, and 100 ppm biodiesel was blended with these additions. This article tests diesel engine performance and exhaust emissions utilising Jatropha biodiesel blend and nano additions. An experimental test arrangement assessed performance and emissions at varying loads on a single-cylinder diesel engine. J20Al100 biodiesel blend achieved 6.5% thermal efficiency increase. Compared to all fuels, J20C50 jatropha biodiesel with CNTslowered CO and NOx emissions by 35 and 52%. Compared to alternative fuels, J20T25 jatrophabiodiesel blend with TiO2 decreased HC and smoke emissions by 22 and 50%. Engine performance and emissions were best for nanoparticle-containing jatropha biodiesel (J20Al100, J20T25, and J20C50). [18]

3. METHODOLOGY

3.1 Biodiesel Production Process

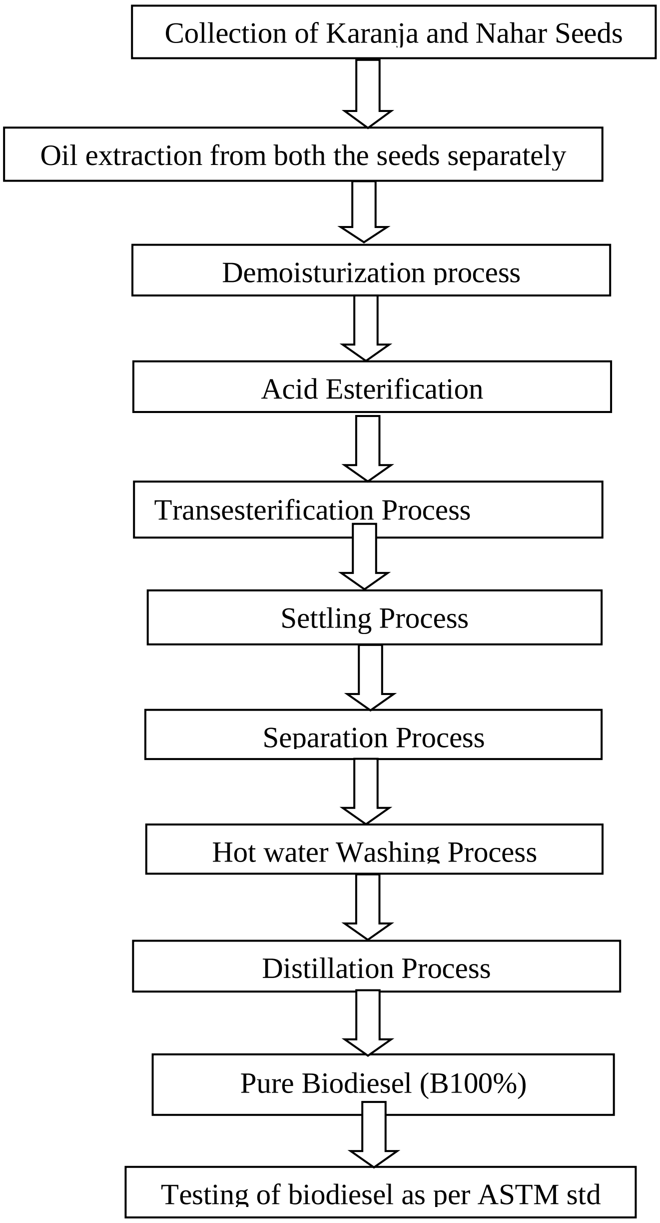


Fig. 1 Biodiesel Production Process

Table 3.4: Properties of Hybrid Methyl Ester

3.2. Preparation of Blends

For the presented work the different blends of diesel and hybrid biofuel (i.e., Blend of Karanja, Nahar and Additives) are used. They are B20 + 2%, B20 + 4%, B20 + 6%, B20 + 8% and B20 + 10% the number after B indicate percentage of volumetric amount of hybrid biodiesel in diesel.[19] These blends are prepared for one litter of each category. The physical and chemical properties were conducted at IBDC, Baramati and are mentioned in Table -1

Table 1: Properties of Hybrid Methyl Ester

Sr.	Test description	Ref. Std. ASTD 6751	Reference		diesel	Hybrid Oil Biodiesel [Undi + WCO] Blends				
			Unit	Limit	B00%	B8%	B12%	B16%	B20%	B24%
1	Density	D1448	gm/cc	0.800-0.900	0.832	0.833	0.834	0.835	0.837	0.838
2	Calorific Valve	D6751	MJ/kg	34-45	42.50	42.40	40.22	42.09	41.90	41.77
3	Cetane no.	D613	-	41-55	49.00	49.45	49.73	49.90	50.13	50.29
4	Viscosity	D445	mm/s	3-6	2.700	-	-		2.96	-
5	Moisture	D2709	%	0.05	0.030	NA	NA	NA	NA	NA
6	Flash Point	D93	°C	-	64.00	67.00	76.00	86.00	92.00	98.00
7	Fire point	D93	°C	-	71	-	-	-	102.0	-

3.4 Blends Preparation by volume

In Preparation on Blends for B20 + 2% Blend we have add 20% Biodiesel & 2% Additives & remaining 78% Diesel.

B20 + 2% = 20 % (Biodiesel) + 2 % (Additives) + 78 % (Diesel)

In Preparation on Blends for B20 + 4% Blend we add 20% Biodiesel & 4% Additives & remaining 76% Diesel.

B20 + 4% =20 % (Biodiesel) + 4 % (Additives) +76 % (Diesel)

In Preparation on Blends for B20 + 6% Blend we add 20% Biodiesel & 6% Additives &

remaining 74% Diesel.

B20 + 6% = 20 %(Biodiesel) + 6 %(Additives) + 74%(Diesel)

In Preparation on Blends for B20 + 8% Blend we add 20% Biodiesel & 8% Additives & remaining 72% Diesel.

B20 + 8% = 20 %(Biodiesel) +8 %(Additives) +72%(Diesel)

In Preparation on Blends for B20 + 10% Blend we add 20% Biodiesel & 10% Additives & remaining 70% Diesel.

B20 + 10% =20 %(Biodiesel) +10 %(Additives) +70%(Diesel)

- **The following are examples of test mixtures:**

B20F02, B20F04, B20F06, B20F08, B20F10.

Fig.3 Different blends of undi oil biodiesel

4. EXPERIMENTATION SET-UP

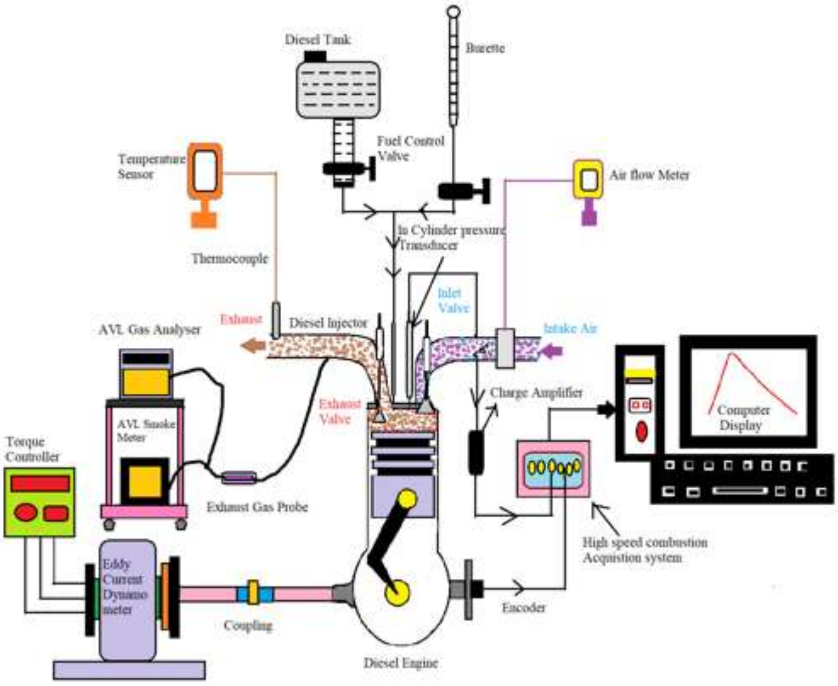


Fig.4 Experimentation Setup[15]

4.1 Engine Specification

Product	Testing the Search Engine Code 240 Single Engine Multifuel
Engine	Produce Kirloskar, Stroke 110 mm, bore 87.5 mm, capacity 661 cc; single cylinder; 4 strokes; liquid cooled. Three and a half kilowatts at 1500 rpm in diesel mode, CR 12–18. 0250 BTDC injector range

4.2 Exhaust Gas Analyzer

Fig.5 Exhaust Gas Analyzer

Table5: Technical specifications for gas analyzer

Measure	Range	Resolution
CO	0-9.99vol.%	0.01%
CO_2	0-20vol.%	0.1%
HC	0-	1 ppm
O_2	0-25vol. %	0.01%

5.RESULTS AND DISCUSSIONS:

5.1 Performance characteristic's

5.1.1Brake thermal efficiency

The change in BTE vs. load at maximum loading was shown in Figure 5.1. Every biodiesel mix and diesel fuel were shown to be efficient as load increased. B20 has the highest efficiency of any blend at the maximum loading condition, at 26.42%. B00's efficiency is just 25.18% at full load.

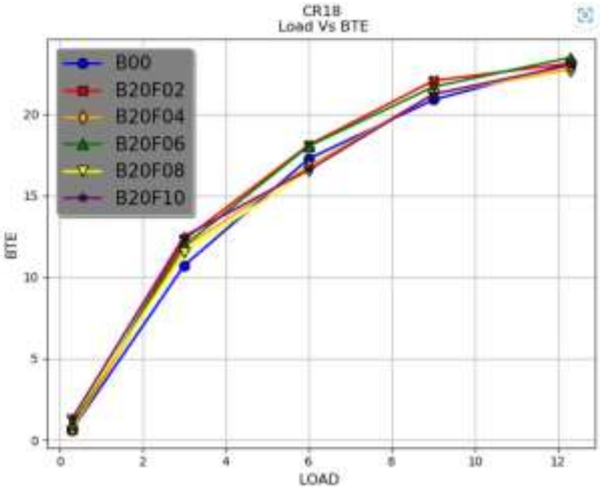


Fig. 5.1- LOAD VS BTE (CR18)

5.1.2Brake Specific Fuel Consumption (BSFC)

The change in load vs. BSFC at maximum loading is seen in Figure 5.2. It demonstrates that the CR18 result of the BSFC was decreasing as the load increased. Compared to B00 diesel fuel, exceptend blends B20F02, B20F04, B20F06, B20F08, and B20F10 have lower BSFC. B20F06 has the lowest BSFC value of the mixes at full load (0.36 kg/kw-hr). B00 has a kg/kW/h of 0.37, whereas B20 has a kg/kW/h of 0.36. One of the primary causes of this is that biodiesel's low heating value is offset by its increase in oxygen concentration, resulting in less bsfc than diesel fuel.

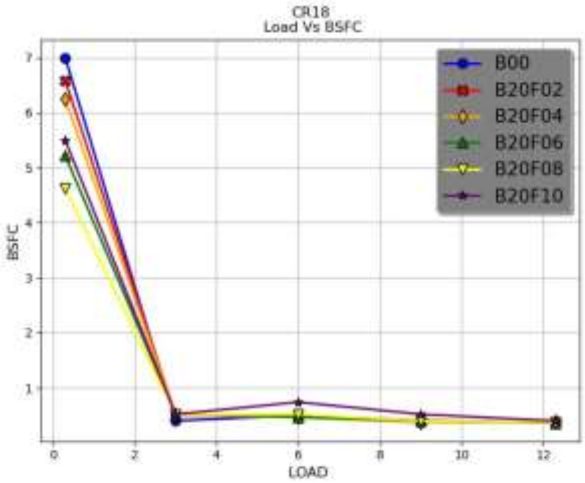


Fig.5.2- LOAD VS BSFC (CR18)

5.1.3 Indicated power

The fluctuation in BTE vs. IP at maximum loading was shown in Figure 5.3. Every biodiesel mix and diesel fuel have been shown to grow in stated power as load rises. All biodiesel blends, with the exception of B20F02, have lower stated power ratings of 6.82 under maximum loading conditions of 12 kg and 3.5 kw of braking power. B20F06 has the highest frictional power of any blend for the maximum loading situation, or 8.73 kw. B00 barely has6.41 kw of frictional power at its full capacity.

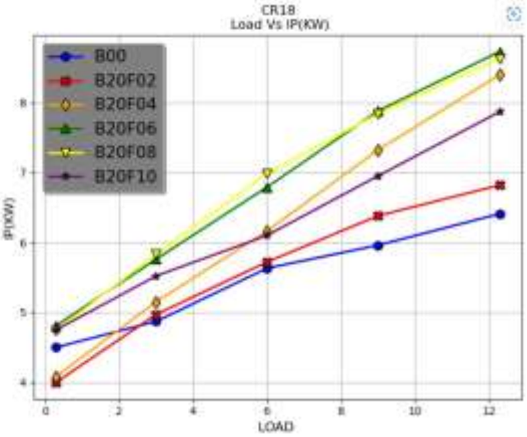


Fig. 5.3- LOAD VS IP (CR18)

5.1.4Mechanical efficiency

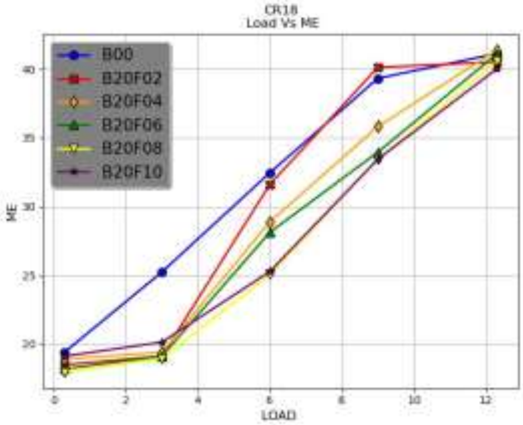


Fig. 5.4- LOAD VS ME (CR18)

Figure 5.4 shows the mechanical efficiency variation for CR 18 under maximum loads. It has been found that mixes with a greater mechanical efficiency of 21.83% are B20F02. The lowest efficiency, B20F06, has a maximum variance in volumetric efficiency of 74.18%. Mechanical efficiency for B00 is 74.59% at the same load. It has been shown that when load and mix ratio increase, mechanical efficiency at CR 18 either rises or falls.

4.2 Emission characteristics

5.2.1Emissions of Carbon dioxide (CO2)

Fuel oxidation from combustion is responsible for the production of carbon monoxide. Inadequate time and oxygen for CO_2 oxidation are the main causes of CO production. Because of a spike in the peak combustion temp and the corresponding increase in the rate of the dissociation process, it can be seen that CO_2 emissions rise as engine load rises.

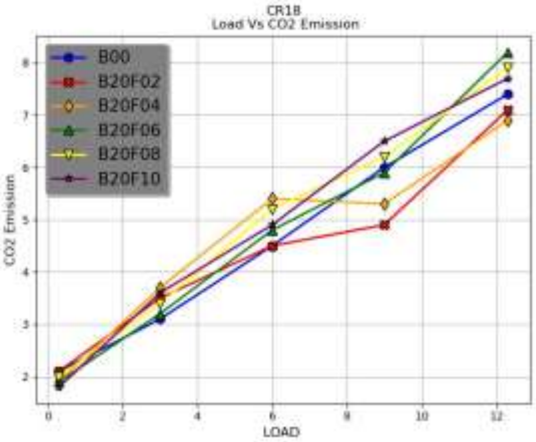


Fig.5.5 LOAD VS CO2 EMISSION

The fluctuation of CO2 with braking power is seen in Figure 5.5. Because diesel fuel has a smaller proportion of oxygen than other undi biodiesel blends (B20F04 excepted), B00 has the greatest CO2 emissions in this situation. Across the board, the CO2 emissions from the mix B20F10 were lower. Here, the percentage of oxygen in fuels is crucial for controlling carbon dioxide emissions. Additionally, it is because biodiesel has a lower carbon footprint than diesel and a higher carbon to hydrogen ratio.

5.2.2Emissions of Carbon Monoxide (CO)

The fluctuation of CO with braking power is seen in Figure 5.6. The graph shows that for all biodiesel mixes and diesel fuel, carbon monoxide emissions are falling as braking power rises. In comparison to the other undi biodiesel blends, the diesel fuel B00 had the greatest CO emissions at maximum loading (0.008%). It was caused by the lower oxygen content of diesel than that of biodiesel.

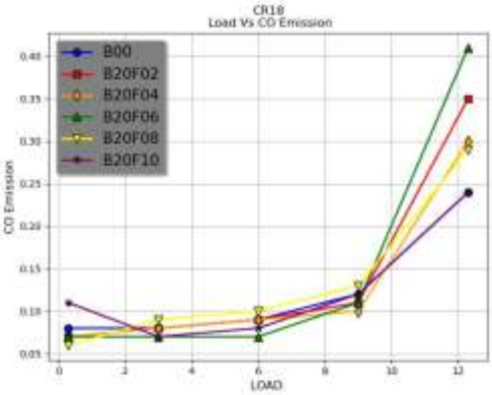


Fig.5.6 LOAD VS CO EMISSION

The lowest emissions among all blends and diesel fuel were produced by B20F04, which also produces around 75% less CO emissions than diesel fuel. Carbon monoxide emissions from the incomplete combustion of diesel fuel are entirely dependent on the mixture's strength, viscosity, and oxygen availability. The fact that biodiesel emissions are decreased may also be a result of additions like methanol and ethanol.

5.2.3Emissions of Hydrocarbon (HC)

HC Vs load fluctuation for B00, B20F02, B20F04, B20F06, B20F08, and B20F10 at CR 18 is shown in Fig.5.7. At low loads, HC emission was lower for all blends than for pure diesel, but as load grew, HC emission increased for blends B00 and B20F10, while blend B20F02 showed 35.97% less HC emission than pure diesel regardless of loads, it was found.

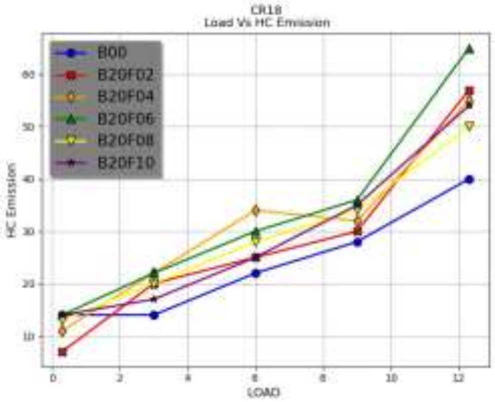


Fig.5.7 LOAD VS HC EMISSION

5.2.4Emissions of Nitrogen Oxide (NO)

The term "nitrogen oxides" (NOx) refers to a group of compounds that include NO, N2O, NO2, and others. While CO and HC are often created as a result of partial fuel combustion, NOx is produced as a result of full combustion when high temperatures are attained. NOx damages lungs, causes throat issues including coughing, and irritates the eyes. NOx (ppm) variation vs load for blends B00, B20F02, B20F04, B20F06, B20F08, and B20F10 at CR 18 is shown in Fig. 5.8. It has been noted that NOx emissions rise as load rises. Figure illustrates that with a compression ratio of 18, NOx emissions are lower for the blends B20F04 and B20F10 than they are for pure diesel.

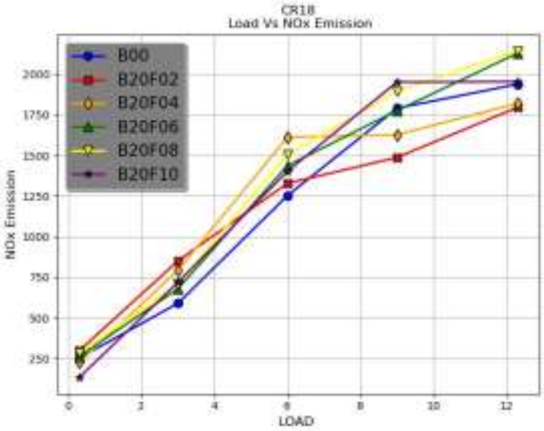


Fig.5.8 LOAD VS NOX EMISSION

4.2.5Emissions of Oxygen(O_2)

The change of O2 emissions with braking power is shown in Figure 5.9, and it was observed that the emissions of O2 rose with load. This could be because biodiesel contains more oxygen than diesel fuel, which aids in a more thorough burning. But additional CO2 was produced as a result of the extra oxygen atom. In this case, biodiesel blend B70 had the highest O2 emissions, whereas mix B20F10 had the lowest.

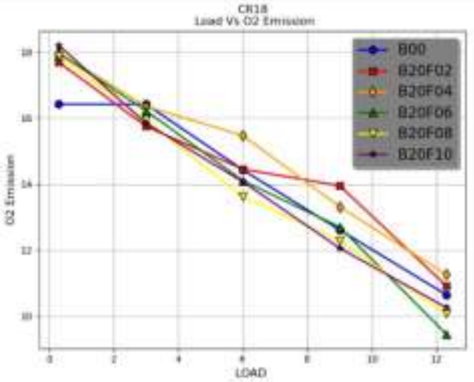


Fig.5.9 LOAD VS O2 EMISSION

5.2.6Smoke OPA

Fuel oxidation from ignition is thought to be the cause of smoke generation. Due to a rise in the peak burning temperature and the corresponding increase in the rate of the dissociation process, it can be seen that smoke OPA increases with increasing engine load.

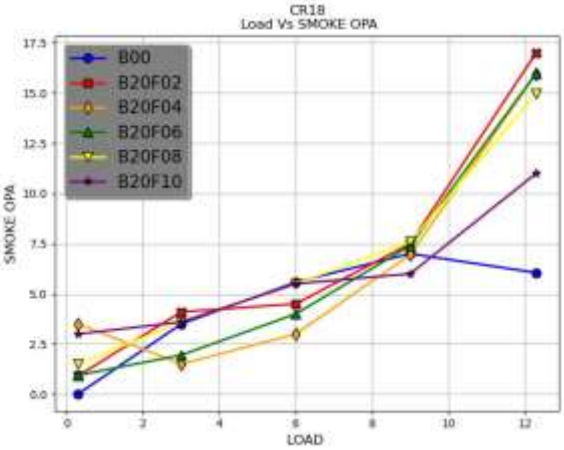


Fig.5.10 LOAD VS SMOKE OPA

Smoke OPA variation with load for blends for B00, B20F02, B20F04, B20F06, B20F08, and B20F10 at CR 18 is shown in Figure 5.10. When compared to pure diesel, smoke OPA for all blends was found to be almost identical at low loads, while B00, B20F02, B20F04, B20F06, and B20F10 with the exception of B20F08 showed a reduction at maximum loads at a compression ratio of 18.

5.2.7Vibration

Vibration vs load variation for blends of B00, B20F02, B20F04, B20F06, B20F08, and B20F10 at CR 18 is shown in Fig.5.11. When compared to pure diesel, vibration is shown to be almost similar for all blends at low load for B00, B20F02, B20F04, B20F06, B20F08 and B20F10, but as load increases, vibration becomes virtually equivalent to pure diesel at compression ratio 18.

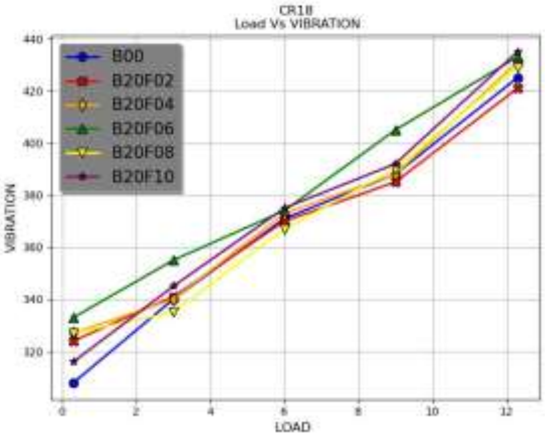


Fig.5.11 LOAD VS VIBRATION

6. ANN VALIDATION

6.1 ANN Modeling

ANNs emulate biological neural networks. New signal processing technologies include ANNs. In this work, an ANN model simulates engine behaviour to produce thermal performance and emission components matching to the best input parameters. The model is based on data from trials on a four-stroke, single-cylinder, variable CR, DI diesel engine utilising biodiesel-diesel mixes as fuel. As said, the studies alter load, compression ratio, engine speed, and mix fraction. The trials use compression ratios of 16 and engine loads of 3 kg, 6 kg, 9 kg, and 12 kg. B00, B08, B16, B20, B24, and B30 mixes are tested.These tests simulate the neural network for engine thermal performance and exhaust gas emissions. This research used MATLAB (ANN Module) for neural network modelling. It's chosen because it's easy to build and train feed forward multilayer neural network models using back-propagation training technique. Matlab (ANN Module) creates multilayer neural networks using Grid data. Neural network input and output layers match grid input and output columns. The optimal number of nodes may be developed in hidden layers linking the input and output layers. Neurons and connection addresses are in each node. It's automated. Importing data from spreadsheets, tab-separated plain text files, comma-separated files, bitmap files, or binary files creates the data grid with input/output matches for neural network training and validation. Manually modify the grid in Matlab (ANN Module). Numeric, text, picture, or combination to build neural networks from grid data. Neural networks learn training data from the grid and self-validate using validation data. After training, neural networks may be evaluated using grid, interactive, or file queries. Matlab (ANN Module) automates neural network creation. Specifying a maximum cycle count or error goal stops learning.

6.2 Comparison of result and parameter variables shown graphically

ANN validation is a method used to verify engine performance. Performance metrics such as braking force, braking thermal efficiency, SFC, volumetric efficiency, emissions temp, & exhaust gases at CR 18 are validated. The regression coefficient (R) and (MSE) are computed using ANN validation. Variable parameters are displayed against the results of performance parameters in graphs.[20]

6.2.1 ANN Graphs for Brake Power

The combined training, testing, validation, and graph for the variable and output brake power parameters is shown in Fig. 6.1. Regression coefficient (R) for training, testing, validation, and all of these together is 0.99711, 0.96381, 0.99206, and 0.9813, which is close to 1.

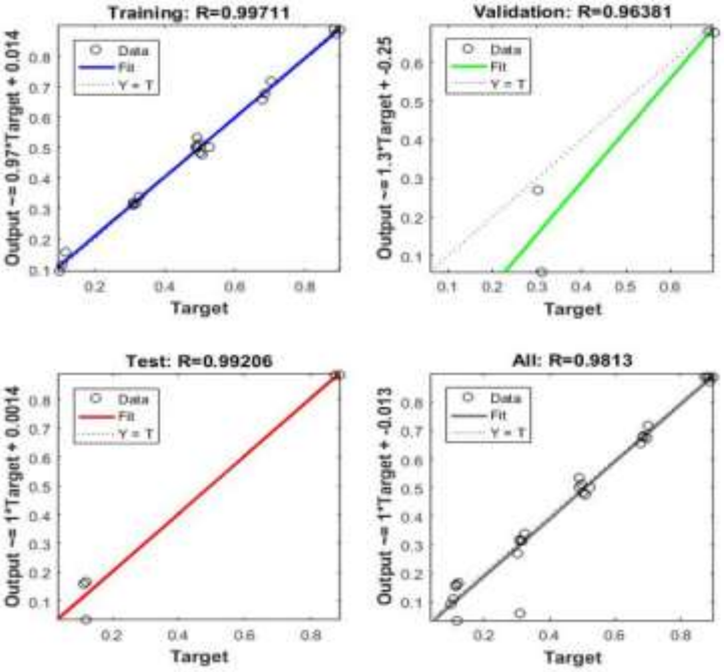
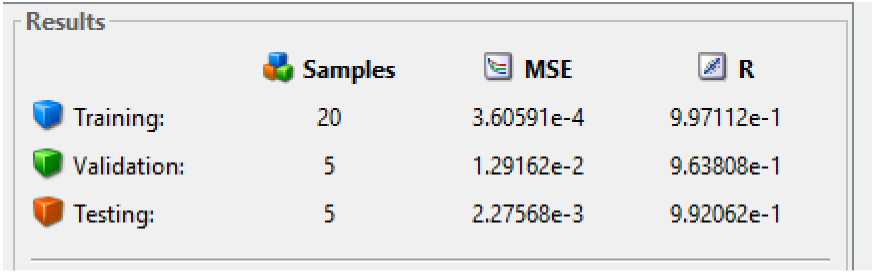


Figure 6.1: Graph for variable output parameters of brake Power

Table 6.1: Result table for Brake power analysis



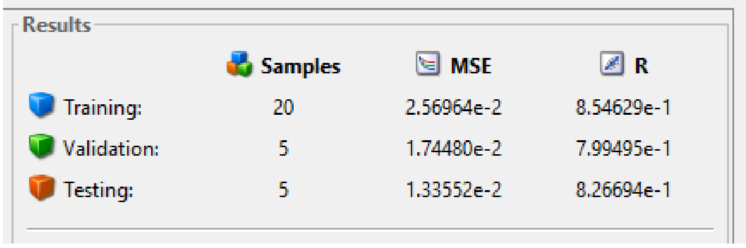
Results

	Samples	MSE	R
Training:	20	3.60591e-4	9.97112e-1
Validation:	5	1.29162e-2	9.63808e-1
Testing:	5	2.27568e-3	9.92062e-1

Results for braking power's variable and output parameters are shown in Table 6.1. According to the graph, the regression coefficients (R) for training, validation, and testing are, respectively, 0.997112, 0.963808, and 0.992062, which are close to 1. MSE, or Mean Square Roots Error, is very close to zero. From this, it may be concluded that ANN validates experimental data.

6.2.2 ANN Graphs for Brake Thermal Efficiency

Table 6.2: Result table for Brake thermal efficiency analysis



Results

	Samples	MSE	R
Training:	20	2.56964e-2	8.54629e-1
Validation:	5	1.74480e-2	7.99495e-1
Testing:	5	1.33552e-2	8.26694e-1

Results for the variable and output brake thermal efficiency parameters are shown in Figure 5.2. Regression coefficients (R) for training, validation, and testing are, respectively, 0.85463, 0.7995, and 0.82669, which are close to 1. From this, it may be concluded that ANN validates experimental data.

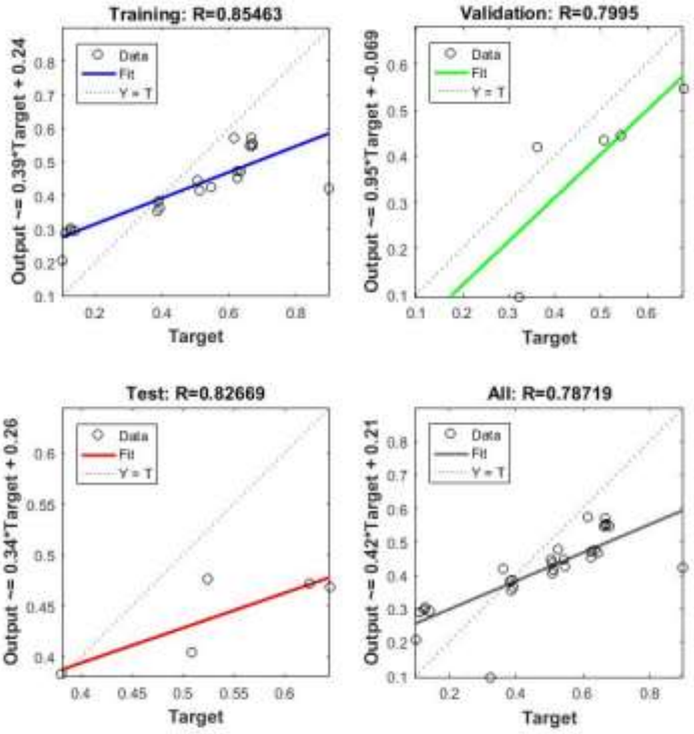


Figure 6.2: Graph for variable output parameters of brake thermal efficiency

6.2.3 ANN Graphs for Specific Fuel Consumption

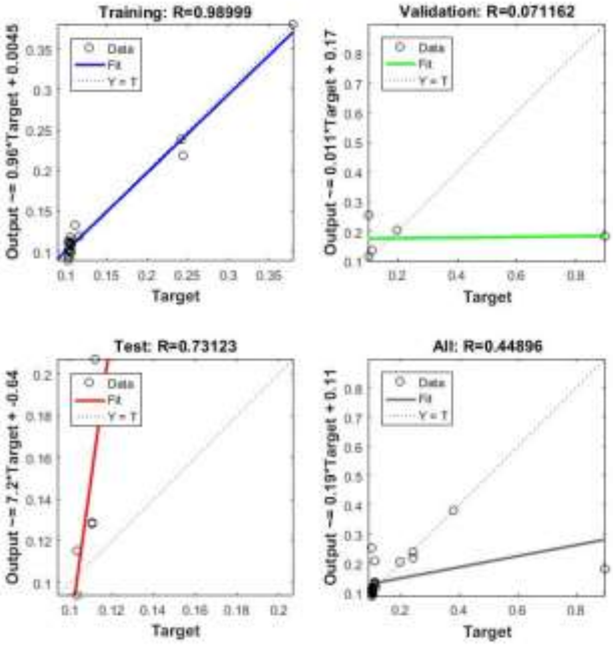
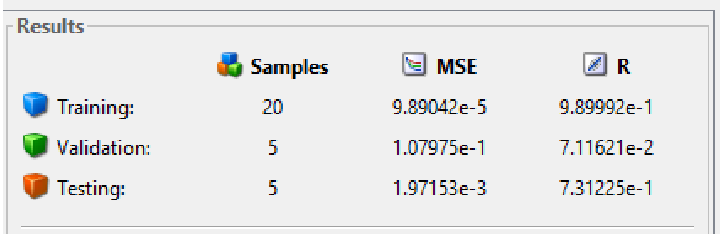


Figure 6.3: Training graph for variable and output parameters of Specific Fuel Consumption

Table 6.3: Result table for Specific Fuel Consumption analysis


Results

	Samples	MSE	R
Training:	20	9.89042e-5	9.89992e-1
Validation:	5	1.07975e-1	7.11621e-2
Testing:	5	1.97153e-3	7.31225e-1

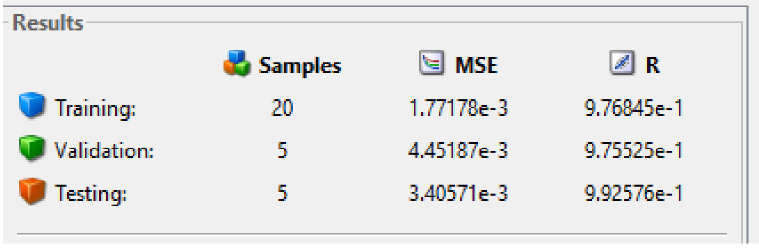
Results for the input and output parameters of Specific Fuel Consumption are shown in Table 6.3. According to the graph, the regression coefficients (R) for training, validation, and testing are, respectively, 0.98992, 0.711621, and 0.731225, which are close to 1. The mean square roots error (MSE), which is close to zero, is 0.000989042, 0.107975, and 0.00197153 correspondingly. This indicates that ANN validates the experimental findings of Specific Fuel Consumption

6.2.4 ANN Graphs for CO Emissions

The training graph for the variable and output parameters of CO Emissions is shown in Figure 6.4. Regression coefficients (R) for training, validation, and testing are 0.976845, 0.975525, and 0.992576, respectively, which are close to 1.

The mean square roots error (MSE), which is close to zero, is 0.00177178, 0.00445187 and 0.00340571 respectively. From this, it can be concluded that ANN validates the experimental data of CO Emissions table

6.4: Result table for CO Emission's analysis


Results

	Samples	MSE	R
Training:	20	1.77178e-3	9.76845e-1
Validation:	5	4.45187e-3	9.75525e-1
Testing:	5	3.40571e-3	9.92576e-1

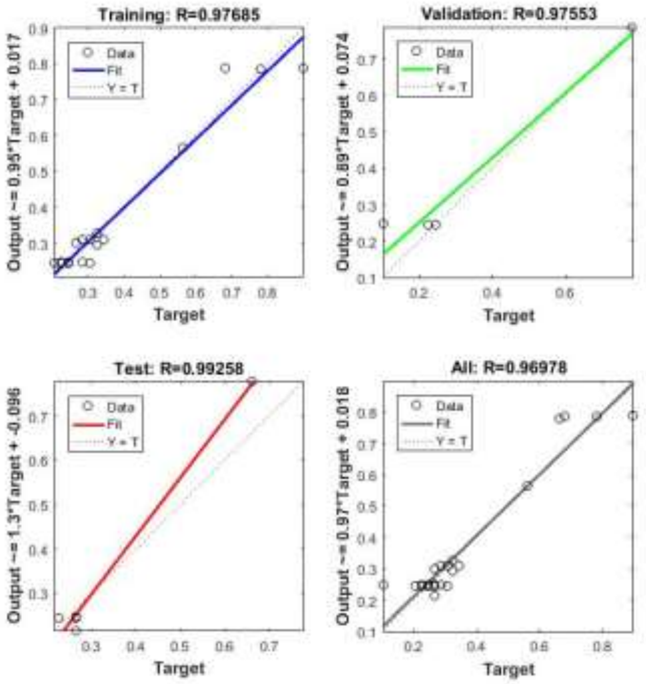
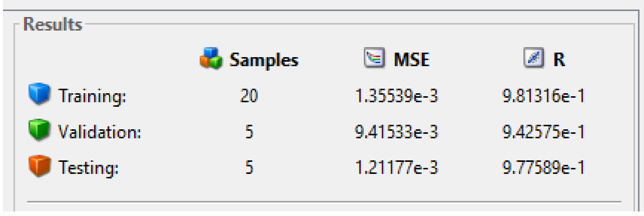


Figure 6.4: Graph for variable and output parameters of CO Emissions

6.2.5 ANN Graphs for Hydrocarbon

Table 6.5: Result table for hydrocarbon analysis



Results

	Samples	MSE	R
Training:	20	1.35539e-3	9.81316e-1
Validation:	5	9.41533e-3	9.42575e-1
Testing:	5	1.21177e-3	9.77589e-1

Figure 6.5 represents training, testing, validation and combined graphs for hydrocarbon respectively. From graphs it is observed that regression coefficient for graphs is 0.981316, 0.942575, 0.977589 and 0.96978 respectively.

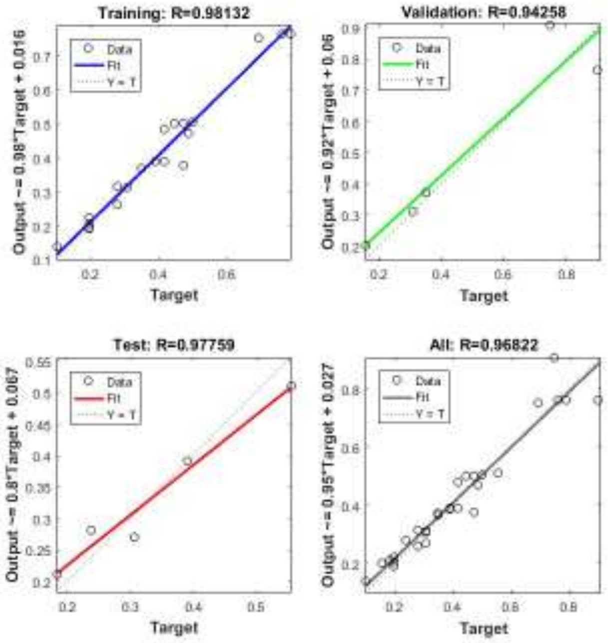


Figure 6.5: Graph for variable and output parameters of HC Emissions.

6.2.6 ANN Graphs for oxides of nitrogen

Training, testing, validation, and combined graphs for nitrogen oxides are shown in Figure 5.7, respectively. It can be shown from graphs that the relevant regression coefficients for graphs are 0.98394, 0.97795, 0.64859, and 0.95123. The graph's overall mean square error is zero. The test result have slight variation with training data because of practical and unavoidable and instrumental error.

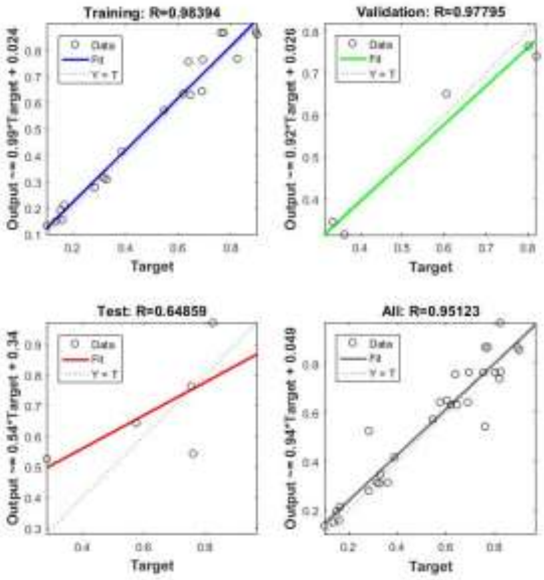
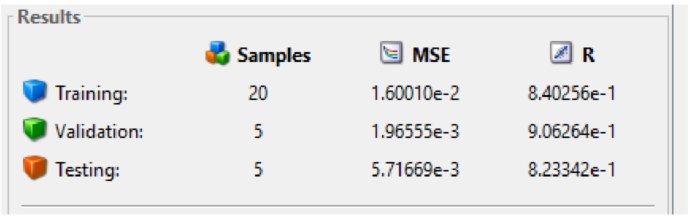


Figure 6.6: Graph for variable and output parameters of NOx Emissions

6.2.7 ANN Graphs for Vibration

Training, testing, validation, and combined graphs for nitrogen oxides are shown in Figure 6.7, respectively. It can be shown from graphs that the relevant regression coefficients for graphs are 0.840256, 0.90626, 0.823342, and 0.99667. The graph's overall mean square error is zero.

Table 6.7: Result table for hydrocarbon analysis



Results

	Samples	MSE	R
Training:	20	1.60010e-2	8.40256e-1
Validation:	5	1.96555e-3	9.06264e-1
Testing:	5	5.71669e-3	8.23342e-1

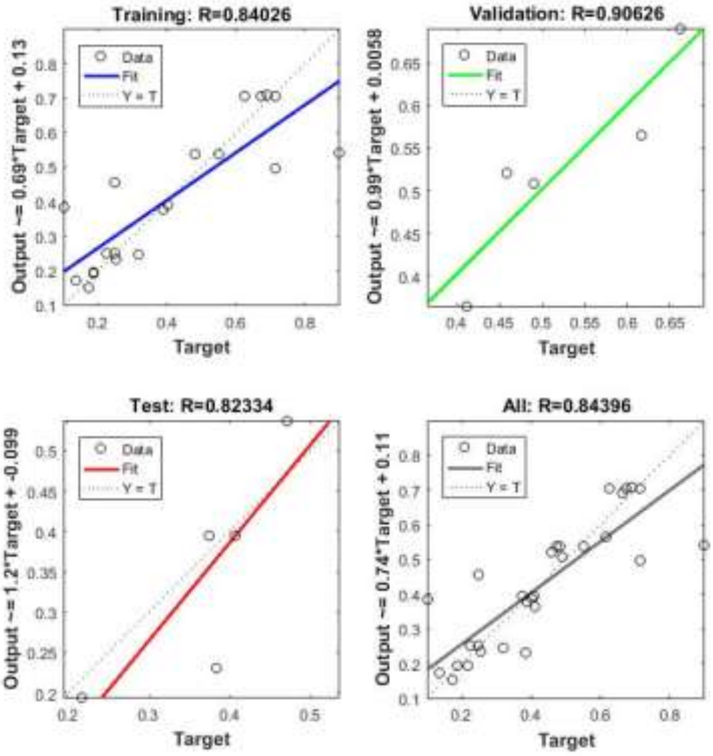


Figure 5.7: Graph for variable and output parameters of Vibration

7. CONCLUSIONS

The experiment was conducted on a single-cylinder, four-stroke diesel engine utilising biodiesel mixes of Undi, WCO, and additives, and the results were compared to diesel fuel.

1. The engine started without difficulty, and Undi, WCO, and additive oil biodiesel blends work well with diesel engines without requiring any setup adjustments.
2. As load rises, engine brake power rises. The amount of heat provided by diesel fuel is greater than that of all blends, with the exception of B20+8%, but since biodiesel blends have an earlier combustion owing to the presence of oxygen, their efficiency exceeds that of diesel fuel. The fact that B20+8% with CR18 has 26.44% higher brake thermal efficiency than standard diesel fuel is encouraging.
3. The BSFC value attained with biodiesel blends is lower than diesel because biodiesel contains more oxygen than diesel, which makes up for the latter's lower heating value. B20+8% has a high efficiency of 0.33%.
4. In terms of volumetric efficiency, it has been shown that the efficiency at CR 18 either rises or falls with an increase in load and blend ratio, and that the efficiency at CR 18 at blends B20+8% rises with an increase in load. Blend B24 has a reduced volumetric efficiency for each load. With the exception of a load of 6 kg, where efficiency is 70.82%, volumetric efficiency is better for B20+8%. The efficiency of volume is shown.
5. Across the board, the CO emissions from biodiesel and its mixes are greater than those from diesel. This is because biodiesel has low volatility, which causes poor mixing, the formation of rich pockets in the combustion chamber, and inefficient combustion, which results in greater CO emission.
6. When compared to diesel at greater compression ratios, biodiesel and its mixes produce less CO2. This occurs as a result of the oxygen presence in vegetable oil.As a result, for a given fuel volume and compression ratio, the carbon concentration is comparatively smaller.
7. For all fuels, the HC emission drops as the compression ratio rises, albeit biodiesel and its blends have greater HC emissions than diesel. Less HC will be released since the gasoline is completely burned at a greater compression ratio. Due to their low volatility and poor mixing, biodiesel and its mixes slow down the chemical process and produce more hydrocarbon emissions than diesel.
8. Due to the greatest temperature being recorded at this compression ratio, NOx emissions are greater across the board for all fuel types at compression ratio 18. However, given greater peak

temperatures were seen with higher compression ratios, it was assumed that the greatest NOx emission would be attained at the highest compression ratio.

9. The O2 emission rises steadily as the compression ratio rises; this is because the O2 emission at CR18 load is higher in all blends, which causes the O2 gas percentages to fall. there is total combustion, therefore the major use of oxygen is to produce CO2. However, with lower compression ratios, more oxygen is required to produce CO and NOx in addition to CO2, so the amount of oxygen in exhaust gases decreases.

10. Exhaust Gas Temperature, or EGT, for biodiesel and its mixes was consistently lower than that of diesel under all circumstances. This could be as a result of biodiesel's low viscosity, which enhances spray production in the combustion chamber and results in a diffusion combustion phase that is less dominating than diesel's.

11. Due to its higher efficiency, B20 might take the role of diesel fuel. B20F8 is also less valuable than BSFC. B20F8 emits much less CO, CO2 HC, NOx, and O2 pollutants than diesel fuel. When additional plantations are made such that it is feasible economically, using Undi, WCO biodiesel may be an option.

12. The ANN is verified (MSE) to determine the regression coefficient (R) and mean square root error. The data is confirmed using ANN since the values of the regression coefficient (R) are nearly equal to 1 and the mean square root error (MSE) is nearly equal to zero for the graph of training, test, and validation for different outputs.

REFERENCES

[1] N. Soni and O. Prakash, “Thermal Analysis of Exhaust Gas of Compression Ignition Engine Using Diesel and WCO Biodiesel Blend,” vol. 3, no. 8, pp. 614–619, 2013.

[2] G. Paul, A. Datta, and B. K. Mandal, “An experimental and numerical investigation of the performance, combustion and emission characteristics of a diesel engine fueled with jatropha biodiesel,” *Energy Procedia*, vol. 54, pp. 455–467, 2014, doi: 10.1016/j.egypro.2014.07.288.

[3] and M. N. Sawarimuthu, S., M. Jaafar, “Performance of various biofuel blends on burner system,” *J. Mek.*, vol. 27, no. 27, pp. 69–77, 2008.

[4] A. S. Silitonga, H. C. Ong, T. M. I. Mahlia, H. H. Masjuki, and W. T. Chong, “Biodiesel conversion from high FFA crude jatropha curcas, calophyllum inophyllum and ceiba pentandra oil,” *Energy Procedia*, vol. 61, pp. 480–483, 2014, doi: 10.1016/j.egypro.2014.11.1153.

[5] A. G. Mohod, P. P. Bhor, K. N. Kadam, S. H. Sengar, and Y. P. Khandetod, “Study of properties of Calophyllum inophyllum L . oil and its biodiesel,” *Int. J.*, vol. 3, no. 1, p. 2010, 2010.

[6] C. DIESEL, “Performance and Testing of Emission Characterstics Bio Fuel Using Diesel Engine With Alexandrian Laurel Seed Oil,” *Int. J.*, vol. 5, no. 12, pp. 342–357, 2021, [Online]. Available: http://ijasret.com/VolumeArticles/FullTextPDF/939_65.PERFORMANCE_AND_TESTING_OF_EMISSION_CHARACTERSTICS_BIO_FUEL___USING_DIESEL_ENGINE_WITH_ALEXANDRIAN_LAUREL_SEED_OIL.pdf

[7] S. Dalvi, S. Sonawane, and R. Pokharkar, “Preparation of biodiesel of Undi seed with in-situ transesterification,” *Leonardo Electron. J. Pract. Technol.*, vol. 11, no. 20, pp. 175–182, 2012.

[8] N. S. Kolhe, A. R. Gupta, and V. K. Rathod, “Production and purification of biodiesel produced from used frying oil using hydrodynamic cavitation,” *Resour. Technol.*, vol. 3, no. 2, pp. 198–203, Jun. 2017, doi: 10.1016/j.reffit.2017.04.008.

[9] D. Kumar and A. Ali, “Potassium ion impregnated calcium oxide as a Nanocrystalline solid catalyst for Biodiesel production from waste cotton seed oil,” *Energy Sources, Part A Recover. Util. Environ. Eff.*, vol. 36, no. 10, pp. 1093–1102, May 2014, doi: 10.1080/15567036.2010.545797.

[10] A. N. Phan and T. M. Phan, “Biodiesel production from waste cooking oils,” *Fuel*, vol. 87, no. 17–18, pp. 3490–3496, Dec. 2008, doi: 10.1016/j.fuel.2008.07.008.

[11] O. D. Samuel, M. A. Waheed, B. O. Bolaji, and O. U. Dario, “Production of biodiesel from nigerian restaurant waste cooking oil using blender,” *Int. J. Renew. Energy Res.*, vol. 3, no. 4, pp. 976–979, 2013.

[12] N. Banerjee, R. Ramakrishnan, and T. Jash, “Biodiesel production from used vegetable oil collected from shops selling fritters in Kolkata,” in *Energy Procedia*, 2014, vol. 54, pp. 161–165. doi: 10.1016/j.egypro.2014.07.259.

[13] M. El-Kassaby and M. A. Nemit-Allah, “Studying the effect of compression ratio on an engine fueled with waste oil produced biodiesel/diesel fuel,” *Alexandria Eng. J.*, vol. 52, no. 1, pp. 1–11, 2013, doi: 10.1016/j.aej.2012.11.007.

[14] A. Fernandes, A. T. Simon, and C. R. C. Lima, “Study of the environmental and technical performance of a diesel engine with the alternative use of biofuel obtained from the reutilization of vegetable oil,” in *Procedia CIRP*, 2013, vol. 7, pp. 335–340. doi: 10.1016/j.procir.2013.05.057.

[15] H. Venu and P. Appavu, “Al2O3 nano additives blended Polanga biodiesel as a potential alternative fuel for existing unmodified DI diesel engine,” *Fuel*, vol. 279, no. May, p. 118518, 2020, doi:

10.1016/j.fuel.2020.118518.
[16] H. A. Dhahad, S. A. Ali, and M. T. Chaichan, “Combustion analysis and performance characteristics of compression ignition engines with diesel fuel supplemented with nano-TiO2 and nano-Al2O3,” *Case Stud. Therm. Eng.*, vol. 20, no. May, p. 100651, 2020, doi: 10.1016/j.csite.2020.100651.
[17] M. S. Gad and S. Jayaraj, “A comparative study on the effect of nano-additives on the performance and emissions of a diesel engine run on Jatropha biodiesel,” *Fuel*, vol. 267, no. January, p. 117168, 2020, doi: 10.1016/j.fuel.2020.117168.
[18] P. Vignesh, V. Jayaseelan, P. Pugazhendiran, M. S. Prakash, and K. Sudhakar, “Nature-inspired nano-additives for Biofuel application – A Review,” *Chem. Eng. J. Adv.*, vol. 12, no. July, p. 100360, 2022, doi: 10.1016/j.ceja.2022.100360.
[19] H. S. Anantha Padmanabha and D. K. Mohanty, “Impact of additive ethylene glycol diacetate on diesel engine working with jatropha-karanja dual biodiesel,” *Renew. Energy*, vol. 202, no. November 2022, pp. 116–126, 2023, doi: 10.1016/j.renene.2022.11.090.
[20] D. S. N. B. Niraj B Dole.,Dr. Rahul Barjibhe., “Experimentally Investigate and ANN Validation of Performance Parameter on Application of Microalgae Methyl Ester on 4S Diesel Engine .,” vol. 10, no. 5, 2021, doi: 10.15680/IJIRSET.2021.1005026.