

STABILITY OF BIODIESEL AND THE EFFECT OF JULIFLORA OIL AND JAMUN OIL BLENDS ON ENGINE PERFORMANCE AND EMISSION

Submitted in partial fulfilment of the requirements of the award of
Bachelor of Engineering degree in Mechanical Engineering

By

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DEPARTMENT OF MECHANICAL ENGINEERING

SCHOOL OF MECHANICAL ENGINEERING

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INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited with grade "A" by NAAC

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the genuine work of **SIDDA KRISHNA CHAITHANYA** (Reg. No. **3815108**) and **VANGANURI BHARGAV RAM** (Reg. No. **38150122**), who worked on the project "STABILITY OF BIODIESEL AND THE EFFECT OF JULIFLORA OIL AND JAMUN OIL BLENDS ON ENGINE PERFORMANCE AND EMISSION" under my supervision from September 2021 to April 2022

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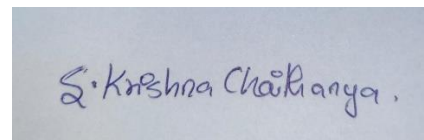
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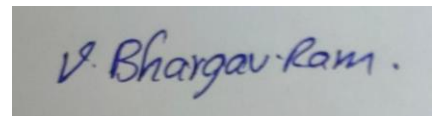
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DECLARATION

We, **SIDDA KRISHNA CHAITHANYA (38150108)** and **VANGANURI BHARGAV RAM (38150122)** hereby declare that the Project Report entitled “**STABILITY OF BIODIESEL AND THE EFFECT OF JULIFLORA OIL AND JAMUN OIL BLENDS ON ENGINE PERFORMANCE AND EMISSION**” done by us under the guidance of **Mr. S. LAKSHMI SANKAR, M.E.,(Ph.D.)** is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in Mechanical Engineering.



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Abstract

In biodiesel, long-chain unsaturated fat esters are obtained from a variety of sources, including vegetable oils, animal fats, and waste oils. Unsaturated fats, which are prone to oxidation, are found in a variety of forms, quantities, and configurations in biodiesel. Collaboration with air oxygen, light, temperature, capacity condition, and variables producing formation affect the strength of biodiesel. There are three main categories of biodiesel oxidation stability, warm strength and capacity soundness. When biodiesel comes into touch with oxygen-consuming materials, as well as metal foreign contaminants, oxidative degradation occurs. When temperatures rise, the oxidation rate increases, resulting in the formation of insoluble and an increase in oil and fat weight. This is a sign of warm dangerous. The relationship between biodiesel's physical and chemical properties and environmental factors is a major concern for capacity soundness., nevertheless. for example, light, metal defilement, shading changes, and rearrangement. The BSFC of biodiesel fuel with cell reinforcement is not exactly that of fuel without cancer prevention agent. Besides, a cancer prevention agent can essentially lessen NOx development during engine activity. Among other things, this page provides an overview of the reliability of biodiesel, as well as the methods available to predict its various security aspects. Plausible solutions for work on the soundness of biodiesel and the impact of cancer prevention agents in settled mixes on motor execution and outflow are additionally talked about.

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LIST OF SYMBOLS AND ABBREVIATIONS

O ₂	-	Oxygen
CO ₂	-	Carbon Dioxide
CO	-	Carbon Monoxide
HC	-	Hydro Carbon
NOX	-	Nitrogen oxides
BP	-	Load
BTHE	-	BRAKE THERMAL EFFICIENCY
SFC	-	SPECIFIC FUEL CONSUMPTION

CHAPTER-1

INTRODUCTION

1.1 BACKGROUND

An oil-based diesel fuel made from long-chain alkyl esters found in vegetable oil or animal fat is known as biodiesel. Unsaturated fat esters are formed by intentionally reacting lipids (e.g. vegetable oil, animal fat) with an alcoholic solution to make biodiesel. Biodiesel's unsaturated fat profile is comparable to that of parent oil or fat, and this is an important factor that influences the fuel's quality. Fuel's steadfastness references to its protection against corruption processes that might alter its fuel qualities and render it ineffective as a fuel. The unsoundness of a fuel can be determined by observing its behaviour, for example, When it undergoes oxidation or autoxidation in the presence of oxygen in the surrounding air, warm or warm oxidative crumbling due to warmth, hydrolysis when in contact with water or clamminess in tanks and fuel lines, or microbial pollution from water drops containing small organic entities or developments, or the movement of buildup particles into the actual fuel.

1.2 BIODIESEL

Biodiesel's robustness incorporates the parts of oxidation, warmth, and limit strength. Oxidation strength is the inclination of fills to reply with oxygen at encompassing temperature. Biodiesel debasement preceding burning in diesel motor is impacted by various elements, for instance, the idea of the underlying lipid feedstock, the biodiesel creation cycle, the capacity and treatment of conditions, fuel added substances and defilements, the circumstances inside the fuel tank and the fuel transport system. In order to estimate a fuel's ability to provide asphaltene at high temperature settings, the fuel is heated. Asphaltenes are tar-like resinous mixtures created by the fuel, and when utilized as fuel, these substances stop up the fuel channels of motors. The temperature essentially affects oxidative debasement since it upgrades the pace of debasement. Shaky oxidation items can go after

elastomers. Hydroperoxides, which might go after elastomers or polymerize to shape unmanageable gums, are worked on by the oxidation of biodiesel. Hydroperoxides and carboxylic acids, for instance, may go about as plasticizers for elastomers when utilized as oxidation things. Capacity dependability is a measure of the fuel's overall stability while being stored for lengthy distances. Oxidative corruption is maybe one of the underlying worries of capacity security, however microbial development and water tainting are unequivocal issues of capacity steadiness over the long haul .A few past examinations have previously researched the oxidation, warm, and capacity strength of biodiesel . Audits of biodiesel's soundness and the effects of oxidation inhibitors on engine performance and emissions have been few and far between. Biodiesel's soundness can be measured using a few different techniques, including the treatment of greasy oil or ester at elevated temperatures, times, and oxygen openness while estimating at least one oxidation-touchy property, such as peroxide esteem, insoluble, the development of unstable short chain unsaturated fats, or fieriness of response. Nonetheless, no basic steadiness test or single strength boundary at present exists to adequately show all the steadiness highlights of biodiesel fuel. A single new test that can completely assess the strength of biodiesel is very unlikely since multiple tests have varying capabilities. Biodiesel's oxidation, heat, and capacity soundness, as well as various testing methods, are examined in the present research. Accepted Manuscript enhancement of biodiesel dependability is also discussed.

Biodiesel oxidation robustness, the strategies used to further develop it, the impact of oxidation inhibitors (i.e., cell support) on adequacy, and the effect of disease counteraction specialist treated blend on diesel engine execution and surge qualities are the focal point of this article. A few parts of biodiesel soundness The solidness of biodiesel is impacted by its associations with oxygen, light, temperature, limit conditions, and factors that cause residue game plan. Biodiesel conveyed from vegetable oils and various feedstocks is less steady than fuel based diesel due to the unsaturated fats, for example, linoleic and linolenic acids, that make up the unsaturated fat

profile of the parent feedstock. The safety of biodiesel is dependent on a variety of unsaturated fat production. Poly unsaturated fats are methylene-hindered rather than produced in the vast majority of plant-derived fatty oils. This primary property is crucial for the comprehension of the security. In this manner, the shakiness of biodiesel can be partitioned into three viewpoints, specifically, oxidative, warm, and capacity insecurity. The vulnerability of biodiesel is subject to the total and game plan of the olefinic unsaturation in the unsaturated fat chains.

Oxidation strength The oxidation of unsaturated fat chain is a tangled approach on account of its different applications. Biodiesel oxidation is achieved by unsaturation in the unsaturated fat chain and the presence of twofold security in the unsaturated fat atom, which shows raised degrees of reactivity with O₂, especially when acquainted with air or water. Unsaturated sleek mixes are utilized to coordinate oxidation reliable quality, since low proportions of the multitude of additional significantly unsaturated oily combinations have an excessively solid impact in lessening oxidation stability. Thus, the oxidation component can be made sense of by two classifications, in particular, essential oxidation and optional oxidation. Various specialists have researched the science of essential and optional oxidation. A couple of studies have shown that vinyl polymerization includes more noteworthy atomic weight oligomers of oily oils or ester advancement. Crucial oxidation happens through a great deal of responses named inception, prompting, and end.

Carbon-free revolution is made possible, as shown, by disposing of hydrogen from the main set.. A peroxy revolutionary may be formed in a matter of minutes if diatomic oxygen is accessible, even if the carbon-based free revolutionary does not have considerable options. It is more lively to be a carbon-free revolutionary than a peroxy-free one. It doesn't matter since hydroperoxide and carbon extremists can quickly extract hydrogen from peroxy free revolutionary, which is sensitive enough (ROOH). The freshly framed free carbon revolutionary may answer with diatomic oxygen and continue with the enlightenment cycle. .Inception: $RH + I \cdot \rightarrow R \cdot + IH$ Engendering: $R \cdot + O_2 \rightarrow$

$\text{ROO}\cdot + \text{ROO}\cdot + \text{RH} \rightarrow \text{ROOH} + \text{R}\cdot$ End: $\text{R}\cdot + \text{R}\cdot \rightarrow \text{R-R}$ $\text{ROO}\cdot + \text{ROO}\cdot \rightarrow \text{Stable items}$. Essential oxidation response During the acceptance time frame, the ROOH buildup focuses stays low until a particular stretch of time, and the oxidation robustness of unsaturated fat or biodiesel not set in stone under pressure conditions. For the whole oxidation system, the ROOH level augmentations quickly until the underlying time frame is arrived at . During the underlying time frame, ROOH can straightforwardly or by implication change the properties of oily oils and biodiesels . ROOH structures at 300-400 meq O₂/kg at any ROOH center profile top, despite the fact that the degree of greater ROOH has been studied. When the atomic oxygen is combined with the first substrate, RH, a shaky peroxide revolutionary (ROO) is formed. An unsaturated fat hydroperoxide will be created if a hydrogen atom from unsaturated lipids is transferred to a peroxide revolutionary (ROOH).

Eq. (1) depicts the extremist chain reaction, in which the oxygen reaction brings about the arrangement of a new unsaturated fat extremist (R), as a result of the growth of unsaturated fat hydroperoxide (ROOH) and the self-sustaining chain response. $\text{R}\cdot + \text{O}_2 \rightarrow \text{ROO}\cdot$ $\text{ROO}\cdot + \text{RH} \rightarrow \text{ROOH} + \text{R}\cdot$ (1) When two free extremists reply and frame stable things, as shown in the preceding criteria, the last step is completed. $\text{R}\cdot + \text{R}\cdot \rightarrow \text{R-R}$ (2) $\text{ROO}\cdot + \text{ROO}\cdot \rightarrow \text{stable items}$ (3) Whenever a sufficient grouping of revolutionary species is accessible, the likelihood of two extremists impacting is extremely high 11. Peroxyl progressives (ROO) can make peroxyl-associated molecules(R-OO-R) and liberating oxygen as go on accordingly (4) $\text{ROO} + \text{ROO} \rightarrow \text{R-OO-R} + \text{O}_2$ (4). The ROOH obsession is extremely low all through the significant season of oxidation until a specific time span, which is now and again alluded to as the selection time span, is reached (IP), The presence of temperature and oxygen strain during IP is separate by the overall openness to oxidation of TAG or alkyl ester, which shows the beginning of fast oxidation; the ROOH level quickly augments when the IP has passed. The hydroperoxide (ROOH) levels can either top and thusly diminishing or expansion and level at a consistent state as oxidation advances. Ignoring the way that issues, for example, level of prior oxidation, temperature, oxygen

accessibility, and repeat of metal powers, are possible attracted with these idiosyncrasies, the clarifications for the two unique exercises stay unclear. ROOH deterioration proceeds due to a top in ROOH fixation. An absence of oxygen in the room might impede or even halt the ROOH setup. Other variables such as greater temperatures and the presence of hydroperoxide degrading metal impetuses (e.g., copper and iron), which increase ROOH degradation rate, might affect ROOH focus. ROOH levels typically peak at 300-400 meq O₂/kg, however greater ROOH levels have been seen. a variety of supplementary oxidation materials, such as short-chain carboxylic acids, alcohols, and high

CHAPTER-2

LITERATURE SURVEY

Proceeded with utilization of petrol based fills is currently broadly perceived as impractical on account of draining supplies and commitment of these energizes to dirty the climate. The test, thusly, is to get sufficient energy supplies basically conceivable expense. Over 1.5 trillion barrels of oil comparable have been created since Edwin Drake penetrated the world's first oil well in 1859. Monetary development is generally joined by proportionate expansion in the vehicle. Energy demand in industrialised countries, as well as in the developing world, and environmental concerns caused by widespread use of petroleum products, make it increasingly important to promote sustainable power sources that have a long life span and a lower environmental impact than conventional ones. One potential option in contrast to non-renewable energy source is the utilization of oils of plant beginning like vegetable oils and non-palatable oils. Use of biodiesel will permit an equilibrium to be looked for between agribusiness, financial turn of events and the climate. The point of this article is to explore to stowed away conceivable outcomes of biodiesel usage in Hungary by the audit of global writing.

Writing a survey on biodiesel manufacture, burning, use, and disposal is the purpose of this post. About 130 researchers contributed their findings between 1980 and 2008, which were compiled for this investigation. In order to fulfil the world's energy needs, an alternative fuel must be developed to replace the diminishing supply of petroleum derivatives. In terms of energy supply, biodiesel is one of the most fantastic and easily accessible options available to the globe today. More than 350 oil-bearing harvests have been identified, with a small number being considered as potential elective powers for diesel engines. Those harvests include: A variety of lubricants and diesel mixtures were tested by scientists and professionals. They found promising results. The majority of the researchers said that transitory motor tests using vegetable oils as a power source were quite positive, but the long-term test results indicated more carbon produced and clogging up oil pollution, which led to motor failure. In order to avoid motor disappointment, they assumed that vegetable oils had

been altered intentionally or combined with diesel. Biodiesel's burning characteristics are comparable to diesel's, except it has a shorter start delay, a higher starting temperature, a greater starting tension, and a higher peak heat discharge. It was assumed that the motor power output would be the same as diesel fuel. Corrosive catalysts and stimuli, on the other hand, were shown to be less effective.

The writing audit of biodiesel creation is introduced in this section. In the initial segment, the different impetuses which are being utilized for biodiesel creation was surveyed exhaustively. In the second part the requirement for immobilized compound, the different immobilization methods and immobilized chemical utilized for biodiesel creation were evaluated fundamentally. The third part in the writing audit was committed to κ -carrageenan, the compounds, the techniques utilized for immobilization utilizing κ -carrageenan and applications were inspected. In the fourth part the variables affecting the biodiesel creation utilizing immobilized lipase was investigated fundamentally and different ideas were given in light of the writing. The last option parts were committed to the immobilized bioreactors, chemical energy, life cycle evaluation, and financial aspects appraisal.

CHAPTER-3

AIM AND SCOPE OF THE PROJECT

3.1 AIM OF THE PROJECT

The main of bio diesel project is to use the waste (used) vegetable or any kind of oil. And make use of the oil and use it as a fuel and give it another life. Instead of throwing it. Making use of biodiesel as vehicle fuel it increases energy security, improves air quality , decreases emissions .

- Provide work in remote areas.
- Through the use of biofuels, promote the use of renewable energy.
- Identification of regions that are suitable for TBOs and the extraction of biofuels.
- Reduce the country's/oil state's import cost. Make organic manure more widely available.
- Reduce hazardous emissions from the burning of Biofuel, which is almost sulphur-free.
- Plant oil-based fuels may be substituted for fossil fuels to reduce greenhouse gas emissions.

3.2 SCOPE OF THE PROJECT

Biodiesel will drastically reduce carbon emissions, particulate matters and unburned fuel and hydrocarbons. And bio diesel also reduces emissions of carcinogenic compounds as much as nearly 85%.To reduce carbon foot print and by using the oils as renewable source

- To use the waste vegetable and seed oils and use them in making of
- bio diesel

CHAPTER-4

MATERIALS AND METHODS

4.1 MATERIALS REQUIRED

The materials which are used for the following project are Juliflora oil, Jamun oil, Diesel, Titanium dioxide catalyst nano-powder

4.2 PREPARING SAMPLES

Four contains different composition of each oil and diesel. Each sample is samples are to be made using the diesel, juliflora oil &jamun oil. Each sample of 400 ml. the samples are named S1, S2, S3 &S4 respectively.

- Four samples of bio diesel namely(S1 S2 S3 &S4) to be prepared with different ratios of diesel and oils
- Each sample consists of 400 ml
- To each sample a catalyst be added and mixed properly .
- Titanium dioxide is the catalyst used.
- To each sample a catalyst be added and mixed properly

Table 4.1 Preparing samples

SAMPLE	JULIFLORA OIL (%)	JAMUN OIL (%)	DIESEL (%)
S1	20 mL(5%)	20 mL(5%)	360 mL(90%)
S2	40 mL(10%)	40 mL(10%)	320 mL(80%)
S3	50 mL(12.5%)	50mL(12.5%)	300 mL(75%)
S4	60 mL(15%)	60 mL(15%)	280 mL(70%)

4.3 ENGINE TESTING AND ANALYSIS

Electric diesel engine with variable compression ratio (VCR) and an eddy current type loading dynamometer. Electric diesel engine with variable compression ratio (VCR) and an eddy current type loading dynamometer

- Compression ratio may be altered without shutting down the engine or altering the combustion chamber geometry thanks to a specifically constructed slanted cylinder block.
- Combustion pressure and crank angle sensors are included in the configuration.

4.4 Engine Details

Table 4.2 Engine details

Product	VCR Engine test setup 1 cylinder, 4 stroke, Diesel with EGR (Comp.)
Product code	234
Engine	Make Kirloskar, Type 1 cyl., 4 stroke Diesel, water cooled, power 3.5kW at 1500rpm, stroke 110mm, bore 87.5mm. 661cc, CR17.5, Modified to VCR engine CR 12 to 18. With electric start arrangement, battery and charger
Dynamometer	Type eddy current, water cooled,
Propeller shaft	With universal joints
Air box	M S fabricated with orifice meter and manometer
Fuel tank	Capacity 15 lit with glass fuel metering column
Calorimeter	Type Pipe in pipe
EGR	Water cooled, SS, Range 0-15%
Piezo sensor	Range 5000 PSI, with low noise cable
Crank angle sensor	Resolution 1 Deg, Speed 5500 RPM with TDC pulse.
Data acquisition device	NI USB-6210, 16-bit, 250ks/s.
Piezo powering unit	Model AX-409.
Temperature sensor	Type RTD, PT100 and Thermocouple, Type K
Temperature transmitter	RTD PT100, Range 0–100°C, 3 Nos; Thermocouple, Range 0-1200 °C, 2 Nos
Load indicator	Digital, Range 0-50 Kg, Supply 230VAC
Load sensor	Load cell, type strain gauge, range 0-50 Kg
Fuel flow transmitter	DP transmitter, Range 0-500 mm WC
Air flow transmitter	Pressure transmitter, Range (-) 250 mm WC
Software	“EngineSoft” Engine performance analysis software
Rotameter	Engine cooling 40-400 LPH; Calorimeter 25-250 LPH
Pump	Type Monoblock
Overall dimensions	W 2000 x D 2500 x H 1500 mm
Optional	Computerized Diesel injection pressure measurement with injection variation 0-25 deg BTDC

4.5 Schematic Diagram of the engine



FIG 4.1 Schematic diagram of engine

The set up has independent board box comprising of air box, two gas tanks for mix test, manometer, fuel estimating unit, transmitters for air and fuel stream estimations, process pointer and motor marker. Rotameters are accommodated cooling water and calorimeter water stream estimation. It shows investigation of ignition with various mixes and investigation of tension volume plot and demonstrated power

4.6 GAS ANALYSER



FIG 4.2 Gas analyser

The resolution ratio of gas analyser is 0.001 FSN (filter smoke number) OR 0.01 mg/m³ its response and analysis time is two minutes. Mainly it is used for checking Petrol, CNG, Gas vehicle pollution check its detection limit is 0.002 FSN or 0.02 mg/m³. Measurement range is 0-10 FSN

- Gas analyser shows the emissions from the combustion
- Gas analyser are used for measuring CO, CO₂, HC, NO, NO_x & O₂ gases from emission measurements from ppm to percentage
- Gas analyser are widely used in various applications such as boilers, furnaces exhaust emission gases and the efficiency of combustion monitoring .

4.7 SMOKE METER



FIG 4.3 Smoke meter

Smoke mistiness meters compute the optical properties of diesel smoke with a backhanded technique for ascertaining diesel particulate outflows. The small portion of light lost in passing the stack is estimated by mistiness, which is a proportion of light weakening. This worth is estimated and recorded straight by a mistiness meter.

- A smoke opacity meter is a device used to diagnose the proper functioning of diesel engine.
- Smoke metres, also known as opacity metres, differentiate and measure the amount of light obstructed in smoke emitted by diesel engines from vehicles such as automobiles, motorcycles, and ships.
- In order to quantify combustion efficiency, a smoke metre shows the density of the resulting smoke.

CHAPTER-5

SAMPLE RESULTS

5.1 SAMPLE-1(S1)

Report Date : Mon, Feb 21, 2022 , Time : 1:25:45 PM
Organization : Engine testing centre, Operator : Operator
Data File : S1.xlsx, Last Modified Date: Thu, Feb 17, 2022,
Config. File : Research Diesel Engine.xls

Engine Details:

The test diesel at IC 1500 rpm is 3.50 kW, which is single cylinder, four stroke, constant speed, water cooled, diesel engine, cylinder bore 87.50 (mm), stroke length 110.00 (mm), connecting rod length 234.00 (mm). , Compression ratio 17.50, scan volume 661.45 (cc)

Combustion parameters:

Specific gas constant (kJ / kg K): 1.00, air density (kg / m ³): 1.17, adiabatic index: 1.41, multi-feed indicator: 1.35, number of cycles: 10, cylinder pressure indicator: 7, smoothing 2, TDC Reference: -12

Performance standards:

Nozzle diameter (mm): 20.00, nozzle modulus. Discharge: 0.60, dynamometer lever length (mm): 185, fuel tube diameter (mm): 12.40, ambient temperature. (° C): 27, Pulse per Revolution: 360, Fuel type: Diesel, Fuel density (kg / m ³): 830, Fuel calorific value (kJ / kg): 42000

Table 5.1 Sample-1(S1) results

Observation Data

Speed (rpm)	Load (kg)	Comp Ratio	T1 (deg C)	T2 (deg C)	T3 (deg C)	T4 (deg C)	T5 (deg C)	T6 (deg C)
1569	0.32	17.50	35.36	38.44	35.36	34.72	139.90	112.97
1549	3.37	17.50	34.97	37.43	34.97	33.59	149.02	117.80
1540	6.36	17.50	34.88	37.75	34.89	33.62	169.29	129.36
1518	9.24	17.50	34.81	38.32	34.81	33.74	189.55	141.45
1494	12.15	17.50	34.75	39.14	34.76	34.01	218.61	159.47

Observation Data

Air (mmWC)	Fuel (cc/min)	WaterFlow Engine (lph)	WaterFlow Cal (lph)
312.92	9.00	150	100
312.94	10.00	150	100
312.92	16.00	150	100
312.94	20.00	150	100
312.93	18.00	150	100

Result Data

Torque (Nm)	BP (kW)	FP (kW)	IP (kW)	BMEP (bar)	IMEP (bar)	BTHE (%)	ITHE (%)	Mech Eff. (%)
0.58	0.10	4.38	4.48	0.11	5.18	1.82	85.64	2.12
6.11	0.99	4.78	5.77	1.16	6.76	17.06	99.31	17.17
11.54	1.86	5.31	7.17	2.19	8.44	20.02	77.10	25.97
16.77	2.67	6.20	8.87	3.19	10.60	22.95	76.32	30.07
22.05	3.45	5.77	9.22	4.19	11.20	32.99	88.16	37.42

Result Data

Air Flow (kg/h)	Fuel Flow (kg/h)	SFC (kg/kW h)	Vol Eff. (%)	A/F Ratio	HBP (%)	HJW (%)	HGas (%)	HRad (%)
57.61	0.45	4.71	157.62	128.53	1.82	10.27	38.30	49.61
57.61	0.50	0.50	159.66	115.68	17.06	7.38	37.29	38.28
57.61	0.80	0.43	160.59	72.30	20.02	5.38	27.32	47.28
57.61	1.00	0.37	162.92	57.84	22.95	5.27	25.05	46.74
57.61	0.90	0.26	165.53	64.27	32.99	7.32	32.75	26.94

5.2 SAMPLE-2(S2)

Table 5.2 Sample-2(S2) results

Observation Data

Speed (rpm)	Load (kg)	Comp Ratio	T1 (deg C)	T2 (deg C)	T3 (deg C)	T4 (deg C)	T5 (deg C)	T6 (deg C)
1567	0.36	17.50	34.75	38.47	34.75	33.79	183.21	151.02
1552	3.46	17.50	34.78	37.82	34.79	33.58	177.19	145.04
1539	6.48	17.50	34.80	37.92	34.80	33.67	187.81	148.88
1518	9.32	17.50	34.79	38.32	34.79	33.84	204.02	156.43
1496	12.16	17.50	34.80	38.92	34.80	34.11	224.85	167.83

Observation Data

Air (mm WC)	Fuel (cc/min)	Water Flow Engine (lph)	Water Flow Cal (lph)
312.92	9.00	150	100
312.92	13.00	150	100
312.93	16.00	150	100
312.93	19.00	150	100
312.91	22.00	150	100

Result Data

Torque (Nm)	BP (kW)	FP (kW)	IP (kW)	BMEP (bar)	IMEP (bar)	BTHE (%)	ITHE (%)	Mech Eff. (%)
0.65	0.11	4.25	4.36	0.12	5.05	2.03	83.36	2.44
6.27	1.02	4.68	5.70	1.19	6.66	13.50	75.48	17.88
11.75	1.89	5.65	7.54	2.23	8.89	20.38	81.12	25.12
16.91	2.69	6.13	8.82	3.21	10.54	24.35	79.92	30.46
22.07	3.46	6.14	9.60	4.19	11.64	27.05	75.08	36.02

Result Data

Air Flow (kg/h)	Fuel Flow (kg/h)	SFC (kg/kW h)	Vol Eff. (%)	A/F Ratio	HBP (%)	HJW (%)	H Gas (%)	H Rad (%)
57.61	0.45	4.22	157.82	128.53	2.03	12.38	52.99	32.59
57.61	0.65	0.64	159.35	88.98	13.50	7.01	35.40	44.09
57.61	0.80	0.42	160.70	72.30	20.38	5.85	30.87	42.90
57.61	0.95	0.35	162.92	60.88	24.35	5.58	28.69	41.38
57.61	1.10	0.32	165.31	52.58	27.05	5.63	27.76	39.56

5.3 SAMPLE-3(S3)

Table 5.3 Sample-3(S3) results

Observation Data

Speed (rpm)	Load (kg)	Comp Ratio	T1 (deg C)	T2 (deg C)	T3 (deg C)	T4 (deg C)	T5 (deg C)	T6 (deg C)
1585	0.13	17.50	34.79	39.12	34.79	34.21	199.95	164.62
1552	3.22	17.50	34.79	38.18	34.79	33.88	188.08	153.80
1540	6.25	17.50	34.79	38.13	34.79	33.89	193.89	155.12
1518	9.17	17.50	34.80	38.70	34.80	34.08	210.52	162.95
1499	12.09	17.50	34.81	39.66	34.81	34.52	239.65	179.54

Observation Data

Air (mm WC)	Fuel (cc/min)	Water Flow Engine (lph)	Water Flow Cal (lph)
312.91	8.00	150	100
312.92	12.00	150	100
312.91	16.00	150	100
312.92	15.00	150	100
312.92	22.00	150	100

Result Data

Torque (Nm)	BP (kW)	FP (kW)	IP (kW)	BMEP (bar)	IMEP (bar)	BTHE (%)	ITHE (%)	Mech Eff. (%)
0.24	0.04	4.67	4.71	0.05	5.39	0.86	101.37	0.84
5.85	0.95	5.02	5.97	1.11	6.98	13.63	85.70	15.91
11.35	1.83	5.55	7.38	2.16	8.69	19.69	79.37	24.81
16.64	2.65	6.06	8.71	3.16	10.41	30.36	99.91	30.39
21.95	3.44	6.16	9.60	4.17	11.62	26.95	75.11	35.88

Result Data

Air Flow (kg/h)	Fuel Flow (kg/h)	SFC (kg/kW h)	Vol Eff. (%)	A/F Ratio	HBP (%)	HJW (%)	H Gas (%)	H Rad (%)
57.61	0.40	10.02	156.03	144.60	0.86	16.22	65.95	16.97
57.61	0.60	0.63	159.35	96.40	13.63	8.48	41.09	36.80
57.61	0.80	0.44	160.59	72.30	19.69	6.27	32.04	42.00
57.61	0.75	0.28	162.92	77.12	30.36	7.80	37.55	24.30
57.61	1.10	0.32	164.98	52.58	26.95	6.62	29.84	36.59

5.4 SAMPLE-4(S4)

Table 5.4 Sample-4(S4) results

Observation Data

Speed (rpm)	Load (kg)	Comp Ratio	T1 (deg C)	T2 (deg C)	T3 (deg C)	T4 (deg C)	T5 (deg C)	T6 (deg C)
1586	0.34	17.50	34.83	39.20	34.83	34.33	199.95	165.55
1551	3.31	17.50	34.81	37.68	34.80	33.72	172.54	141.56
1537	6.39	17.50	34.81	37.87	34.80	33.80	184.31	146.82
1521	9.22	17.50	34.81	38.48	34.81	34.02	203.20	156.62
1500	12.00	17.50	34.80	39.41	34.80	34.48	231.40	173.21

Observation Data

Air (mm WC)	Fuel (cc/min)	Water Flow Engine (lph)	Water Flow Cal (lph)
312.91	9.00	150	100
312.92	12.00	150	100
312.91	16.00	150	100
312.93	19.00	150	100
312.92	17.00	150	100

Result Data

Torque (Nm)	BP (kW)	FP (kW)	IP (kW)	BMEP (bar)	IMEP (bar)	BTHE (%)	ITHE (%)	Mech Eff. (%)
0.61	0.10	4.63	4.73	0.12	5.41	1.94	90.49	2.14
6.00	0.97	4.69	5.67	1.14	6.63	13.97	81.29	17.19
11.59	1.87	5.19	7.05	2.20	8.33	20.07	75.88	26.45
16.73	2.66	6.13	8.79	3.18	10.49	24.14	79.66	30.30
21.78	3.42	6.17	9.59	4.14	11.60	34.64	97.07	35.69

Result Data

Air Flow (kg/h)	Fuel Flow (kg/h)	SFC (kg/kW h)	Vol Eff. (%)	A/F Ratio	HBP (%)	HJW (%)	H Gas (%)	H Rad (%)
57.61	0.45	4.43	155.93	128.53	1.94	14.60	58.67	24.79
57.61	0.60	0.61	159.45	96.40	13.97	7.18	37.13	41.72
57.61	0.80	0.43	160.90	72.30	20.07	5.75	30.20	43.98
57.61	0.95	0.36	162.60	60.88	24.14	5.81	28.56	41.50
57.61	0.85	0.25	164.87	68.05	34.64	8.14	36.96	20.25

5.5 HC EMISSION VS BP(KW) GRAPH

Table 5.5 HC emission vs BP

	0	0.875	1.75	2.62	3.5
S1	3	5	7	9	13
S2	2	6	9	11	14
S3	1	5	7	11	13
S4	4	8	13	15	17
Diesel	2	6	10	15	19

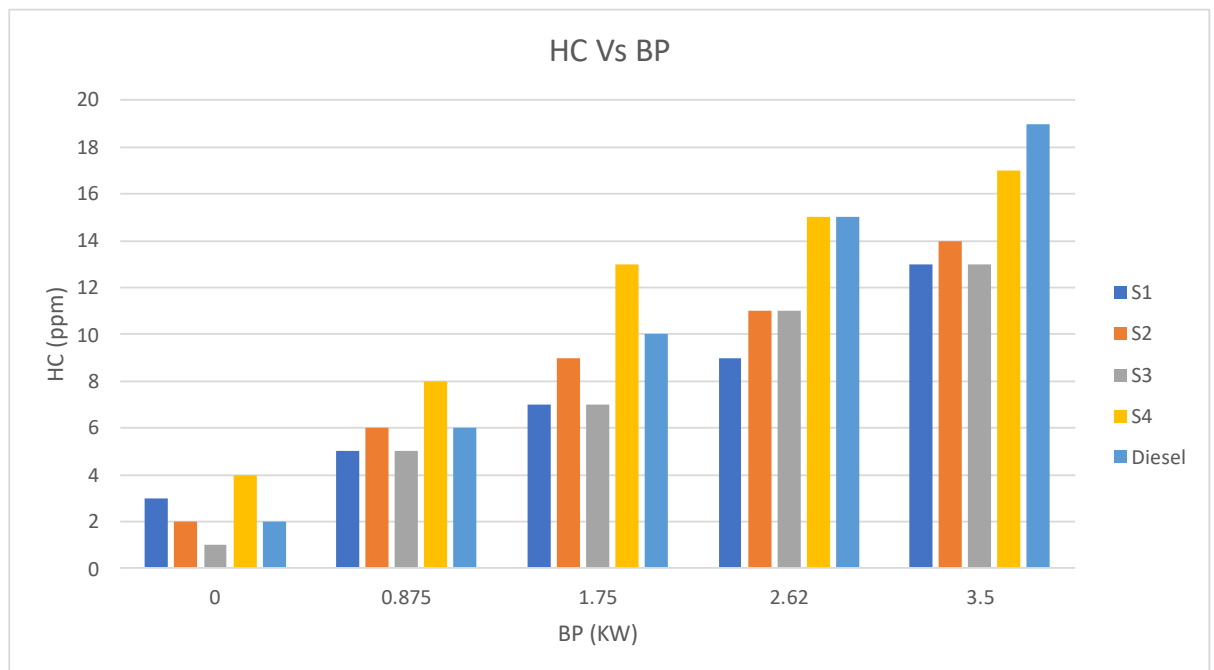


Fig-5.1 HC EMISSION VS BP

For sample S1 at minimum load 0.0875 KW the HC emission is 5 and for maximum load the HC emission is 13. For sample S2 at minimum load 0.0875 KW the HC emission is 6 and for maximum load the HC emission is 14. For sample S3 at minimum load 0.0875 KW the HC emission is 5 and for maximum load the HC emission is 13. For sample S4 at minimum load 0.0875 KW the HC emission is 8 and for maximum load the HC emission is 17.

5.6 CO EMISSION VS BP(KW) GRAPH

Table 5.6 CO emission vs BP

	0	0.875	1.75	2.62	3.5
S1	0.012	0.022	0.032	0.042	0.057
S2	0.0123	0.023	0.034	0.047	0.063
S3	0.017	0.023	0.029	0.034	0.049
S4	0.013	0.027	0.037	0.047	0.058
Diesel	0.008	0.013	0.018	0.023	0.029

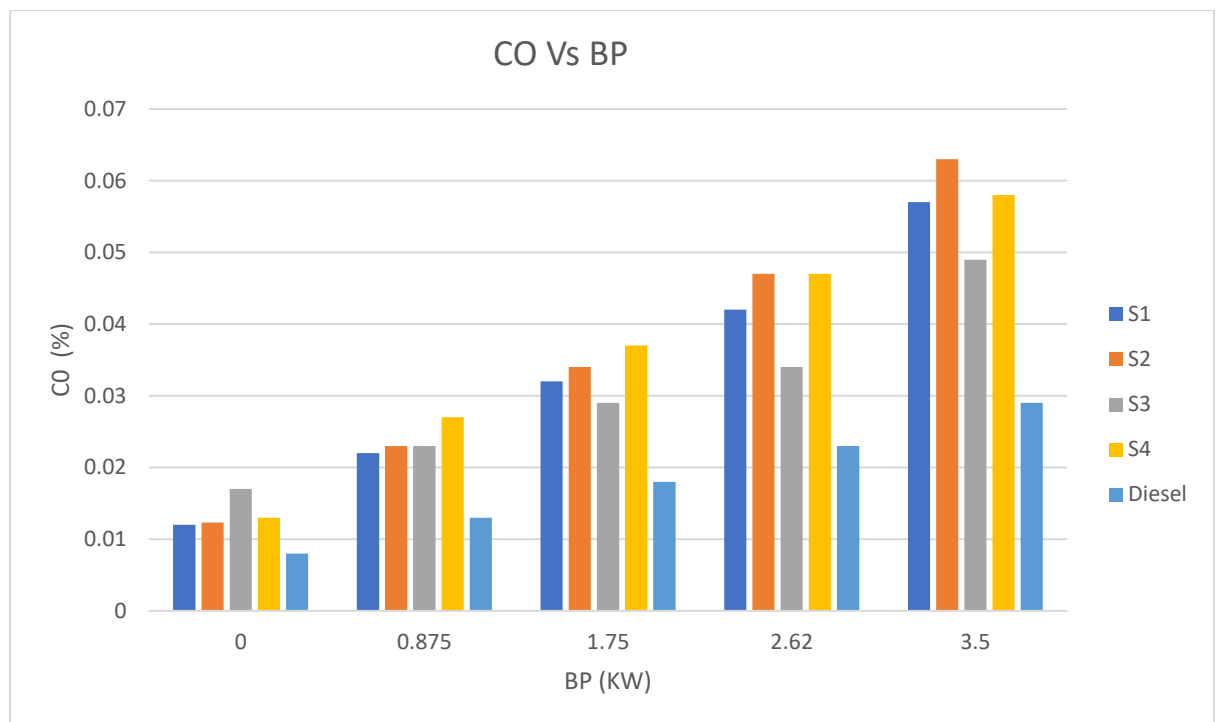


Fig 5.2 CO emission vs BP

For sample S1 at minimum load 0.0875 KW the CO emission is 0.022 and for maximum load the CO emission is 0.057. For sample S2 at minimum load 0.0875 KW the CO emission is 0.023 and for maximum load the CO emission is 0.063. For sample S3 at minimum load 0.0875 KW the CO emission is 0.023 and for maximum load the CO emission is 0.049. For sample S4 at minimum load 0.0875 KW the CO emission is 0.027 and for maximum load the CO emission is 0.058.

5.7 CO2 EMISSION VS BP(KW) GRAPH

Table 5.7 CO2 emission vs BP

	0	0.875	1.75	2.62	3.5
S1	0.6	1.12	1.4	1.59	2.2
S2	0.6	1.3	1.8	1.9	2.5
S3	0.8	0.9	1.2	1.6	1.92
S4	0.7	1.4	1.8	2.1	2.4
Diesel	1.6	1.96	2.54	2.89	2.98

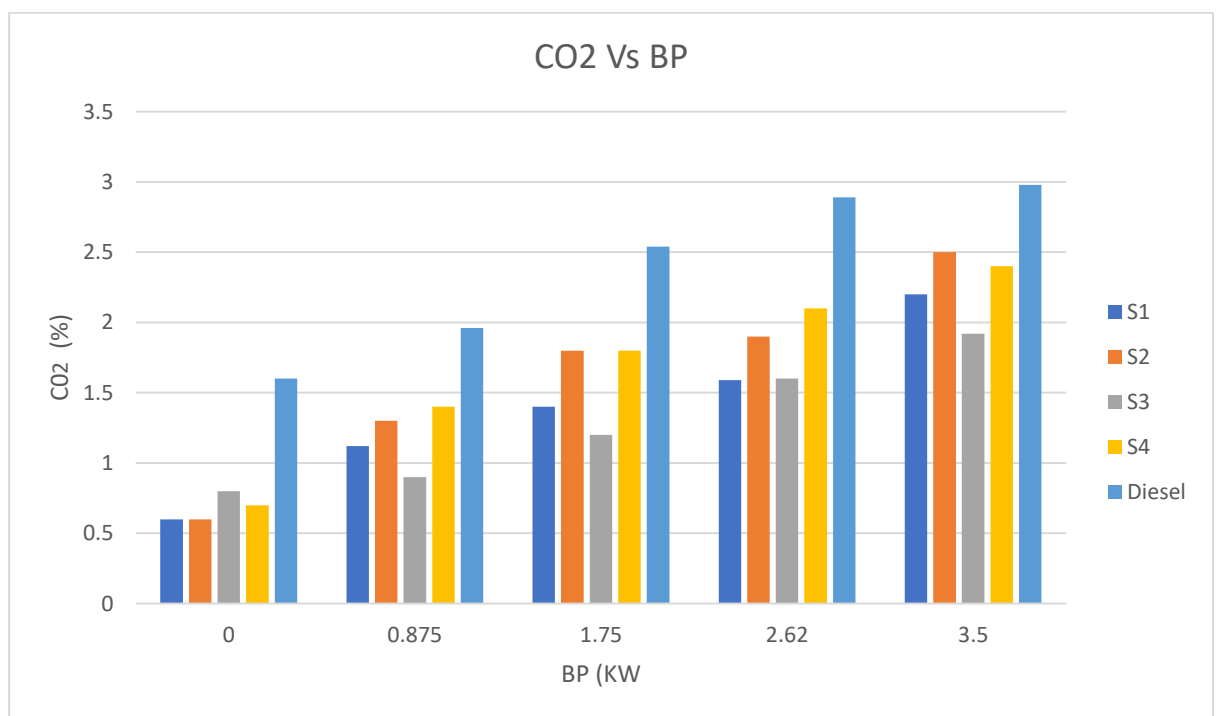


Fig 5.3 CO2 emission vs BP

For sample S1 at minimum load 0.0875 KW the CO2 emission is 1.12 and for maximum load the CO2 emission is 2.2. For sample S2 at minimum load 0.0875 KW the CO2 emission is 1.3 and for maximum load the CO2 emission is 2.5. For sample S3 at minimum load 0.0875 KW the CO2 emission is 0.9 and for maximum load the CO2 emission is 1.92. For sample S4 at minimum load 0.0875 KW the CO2 emission is 1.4 and for maximum load the CO2 emission is 2.4.

5.8 O₂ EMISSION VS BP(KW) GRAPH

Table 5.8 O₂ emission vs BP

	0	0.875	1.75	2.62	3.5
S1	19.89	19.64	18.87	18.5	17.89
S2	19.78	19.02	18.73	18.11	17.78
S3	19.79	18.78	18.42	18.12	17.87
S4	19.66	19.02	18.63	17.78	17.12
Diesel	18	19	15	12	11

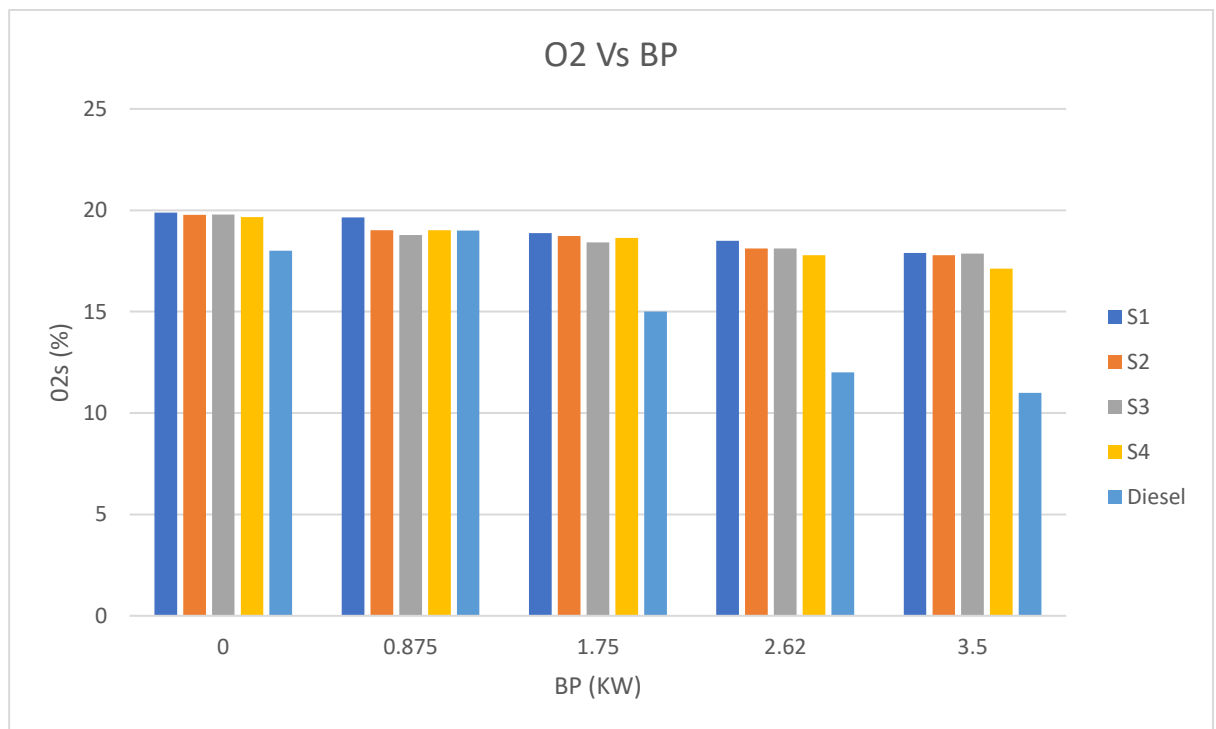


Fig 5.4 O₂ emission vs BP

For sample S1 at minimum load 0.0875 KW the O₂ emission is 19.64 and for maximum load the O₂ emission is 17.89. For sample S2 at minimum load 0.0875 KW the O₂ emission is 19.02 and for maximum load the O₂ emission is 17.78. For sample S3 at minimum load 0.0875 KW the O₂ emission is 18.78 and for maximum load the O₂ emission is 17.87. For sample S4 at minimum load 0.0875 KW the O₂ emission is 19.02 and for maximum load the O₂ emission is 17.12.

5.9 NOX EMISSION VS BP(KW)

Table 5.9 NOX emission vs BP

	0	0.875	1.75	2.62	3.5
S1	87	157	213	305	412
S2	104	197	246	319	473
S3	83	147	233	341	407
S4	107	199	287	342	502
Diesel	56	156	289	485	750

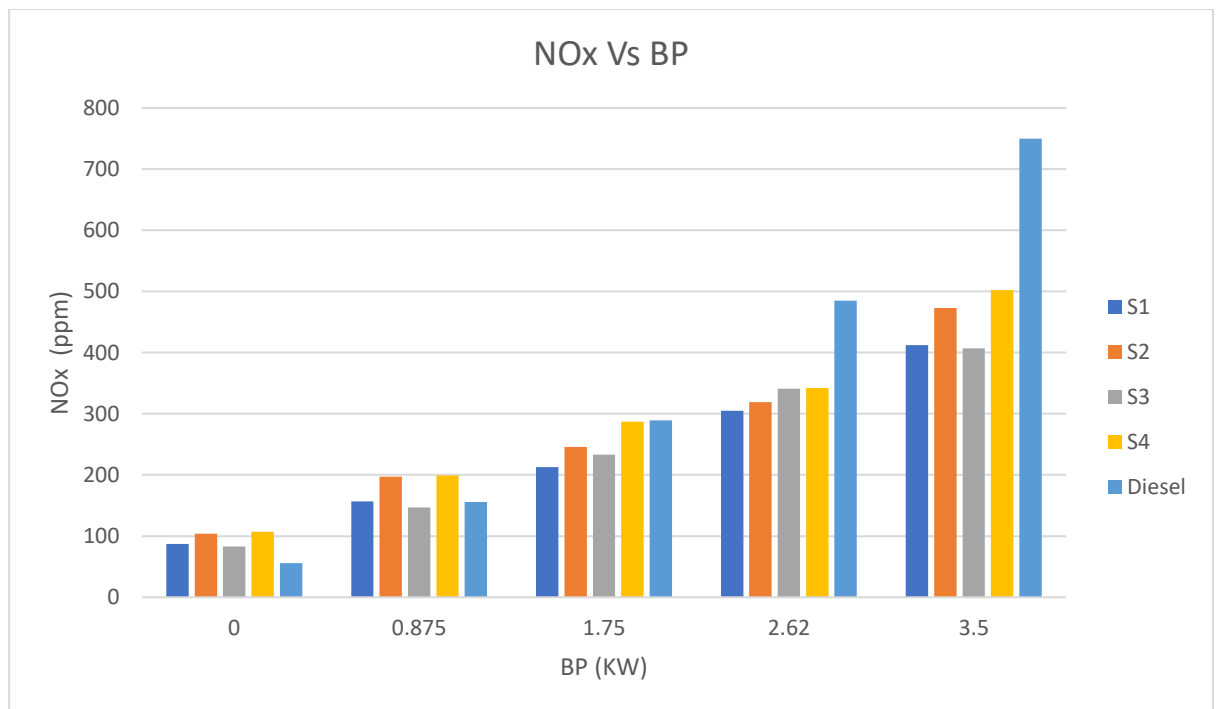


Fig 5.5 NOX emission vs BP

For sample S1 at minimum load 0.0875 KW the NOX emission is 157 and for maximum load the NOX emission is 412. For sample S2 at minimum load 0.0875 KW the NOX emission is 197 and for maximum load the NOX emission is 473. For sample S3 at minimum load 0.0875 KW the NOX emission is 147 and for maximum load the NOX emission is 407. For sample S4 at minimum load 0.0875 KW the NOX emission is 199 and for maximum load the NOX emission is 502.

5.10 BTHE VS LOAD GRAPH

Table 5.10 BTHE vs BP

	0	0.875	1.75	2.62	3.5
S1	1.82	17.06	20.02	22.95	32.99
S2	2.03	13.5	20.38	24.35	27.05
S3	0.86	13.63	19.69	30.36	26.95
S4	1.94	13.97	20.07	24.14	34.64
Diesel	0	16.49	22.75	29.47	32.59

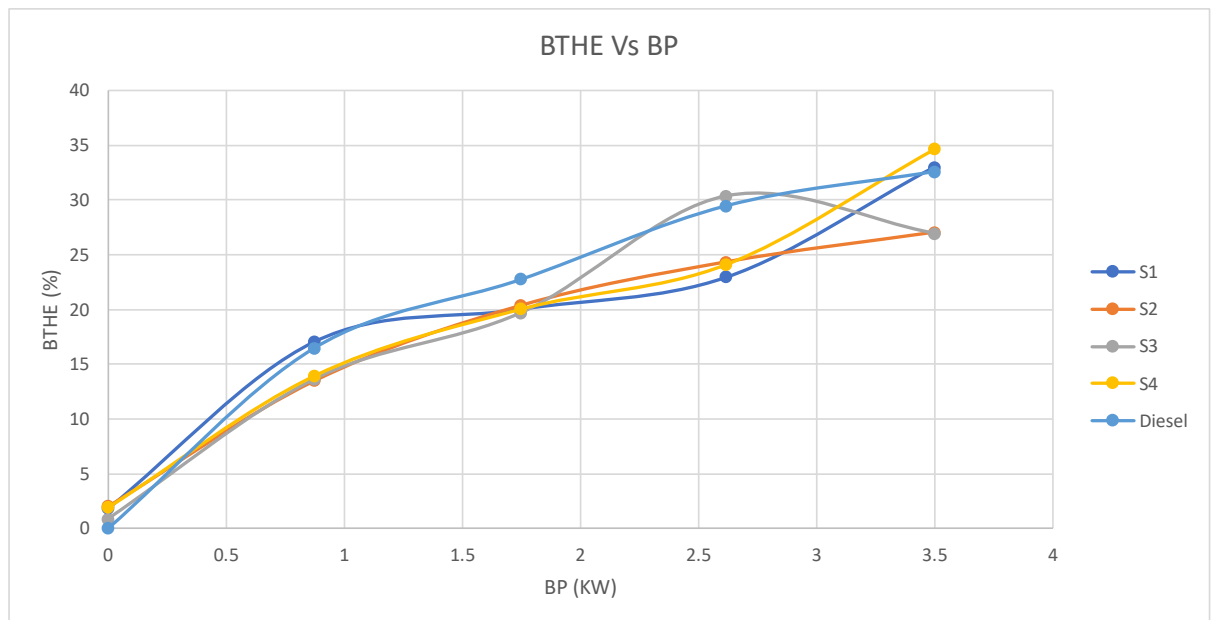


Fig 5.6 BTHE VS BP

For sample S1 at minimum load 0.0875 KW the BTHE is 17.06 and for maximum load the BTHE is 32.99. For sample S2 at minimum load 0.0875 KW the BTHE is 13.5 and for maximum load the BTHE is 27.05. For sample S3 at minimum load 0.0875 KW the BTHE is 13.63 and for maximum load the BTHE is 26.95. For sample S4 at minimum load 0.0875 KW the BTHE is 13.97 and for maximum load the BTHE is 34.64.

5.11 SFC VS LOAD GRAPH

Table 5.11 SFC vs BP

	0	0.875	1.75	2.62	3.5
S1	4.71	0.5	0.43	0.37	0.26
S2	4.22	0.64	0.42	0.35	0.32
S3	10.02	0.63	0.44	0.28	0.32
S4	4.43	0.61	0.43	0.36	0.25
Diesel	3.45	0.52	0.38	0.29	0.2

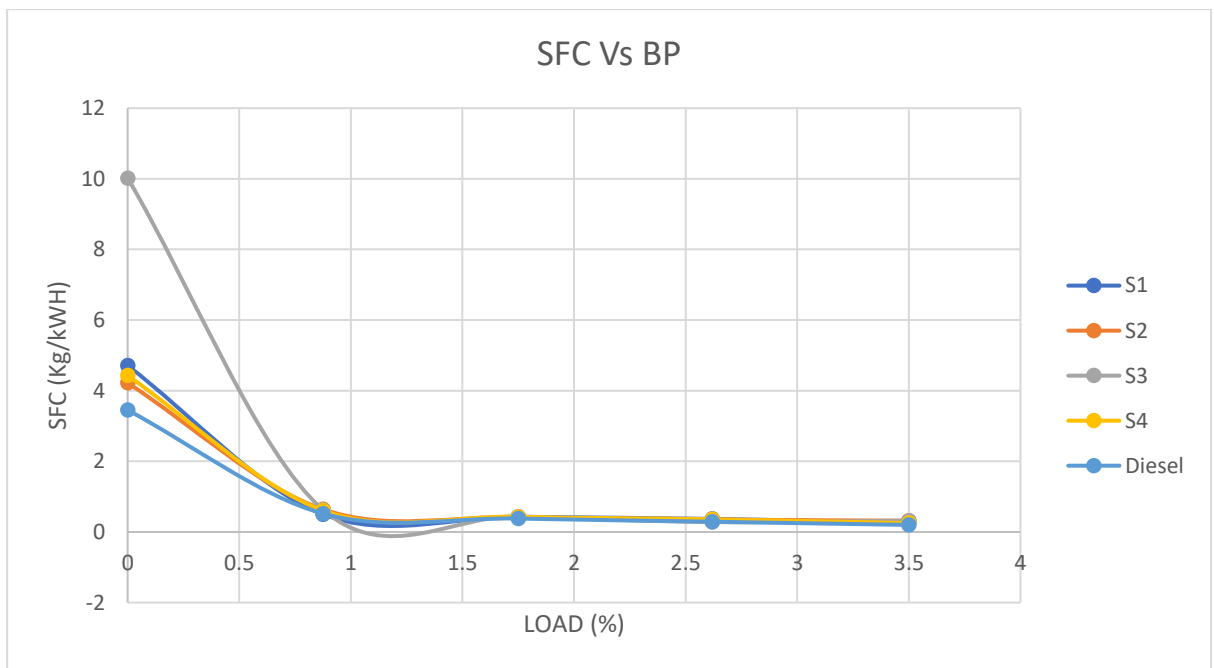


Fig 5.7 SFC vs BP

For sample S1 at minimum load 0.0875 KW the SFC is 0.5 and for maximum load the SFC is 0.26. For sample S2 at minimum load 0.0875 KW the SFC is 0.64 and for maximum load the SFC is 0.32. For sample S3 at minimum load 0.0875 KW the SFC is 0.63 and for maximum load the SFC is 0.32. For sample S4 at minimum load 0.0875 KW the SFC is 0.61 and for maximum load the SFC is 0.25.

CHAPTER 6

SUMMARY AND CONCLUSION

6.1 SUMMARY

Production and use of biofuels - mainly in the light of oats and sugar crops in the light of ethanol and biodiesel in the light of vegetable oils, for example, rapeseed or canola oil - has grown rapidly in recent years and has doubled in the last ten years. The United States and Brazil were the biggest makers of ethanol, with 48% and 31% of ethanol creation overall in 2007. By and by, the European Union represented 60% of worldwide biodiesel production. Countless other nations' states have started, or are thinking about advancing biofuel creation and use.

The main problem these days is that all types of vegetable and fruit oils are wasted after being used. The main aim of bio diesel project is to give second life to those . By using it as an alternate fuel by using it diesel with some quantity of oil and use it as fuel to run vehicles. This helps to reduce the carbon foot print and emissions also. This also decreases the emissions released into the environment. And this is also eco friendly.

In many nations, biofuels remain profoundly reliant upon public help strategy. According to this analysis, support for the production and use of biofuels in the United States, the European Union, and Canada was valued in 2006 at around \$11 billion, and is expected to rise to \$25 billion over the medium term (all medium-term projections in this chief outline allude to the yearly normal for the 2013-17 time frame). A wide range of types of help are given at different phases of biofuel creation and utilize however the three significant classifications of help are:

x Biofuel producers (processing facilities), merchants, and consumers benefit from tax savings, as well as rapid assistance with biomass supply, biofuel generation limitations and yields, blending and specific framework or equipment for biofuel customers.

6.2 CONCLUSION

Biofuels can be utilized for heat, lighting, power and transport. Photosynthesis happens in the chloroplasts of cells and the cycle comprises of two phases: light and dark responses. You may use a variety of natural products (wood, grasses, oils and sugars and starches) as biofuel, including sugars and starches.

From the four samples which we have prepared. Only one out of the four performs very well in emissions and the power output. Bio diesel price is less compared to regular diesel. These days the youth are showing more interest towards the usage of reusable energy sources. So this will be very helpful for such initiatives.

COMBINED ALL EMISSIONS RESULT OF 4 SAMPLES & BTHE, SFC

Table 6.2.1 Out come of the samples

BLEND	HC	CO	CO ₂	O ₂	NOX	BTHE	SFC
S1	3	0.012	0.6	19.89	87	1.82	4.71
	5	0.022	1.12	19.64	157	17.06	0.5
	7	0.032	1.4	18.87	213	20.02	0.43
	9	0.042	1.59	18.5	305	22.95	0.37
	13	0.057	2.2	17.89	412	32.99	0.26
S2	2	0.0123	0.6	19.78	104	2.03	4.22
	6	0.023	1.3	19.02	197	13.5	0.64
	9	0.034	1.8	18.73	246	20.38	0.42
	11	0.047	1.9	18.11	319	24.35	0.35
	14	0.063	2.5	17.78	473	27.05	0.32
S3	1	0.017	0.8	19.79	83	0.86	10.02
	5	0.023	0.9	18.78	147	13.63	0.63
	7	0.029	1.2	18.42	233	19.69	0.44
	11	0.034	1.6	18.12	341	30.36	0.28
	13	0.049	1.92	17.87	407	26.95	0.32
S4	4	0.013	0.7	19.66	107	1.94	4.43
	8	0.027	1.4	19.02	199	13.97	0.61
	13	0.037	1.8	18.63	287	20.07	0.43
	15	0.047	2.1	17.78	342	24.14	0.36
	17	0.058	2.4	17.12	502	34.64	0.25

- Out of the four samples (S1 S2 S3 & S4), S3 has better performance and emissions. It performs well under various loads.

REFERENCES :

- [1]. Yaakob, Z.; Narayanan, B.N.; Padikkaparambil, S.; Unni K., S.; Akbar P., M. An audit on the oxidation strength of biodiesel. Restore. Support. Energy Rev. 2014, 35, 136-153. [Cross Ref]
- [2]. Waynick, J.A. Portrayal of biodiesel oxidation and oxidation items (CRC Project No. AVFL-2b) SwRI® Project No. 08-10721. Natl. Recharge. Energy Lab. 2005, 1-51.
- [3]. Agarwal, A.K.; Khurana, D. Long haul stockpiling oxidation security of Karanja biodiesel with the utilization of cell reinforcements Initiation. Fuel Process. Technol. 2013, 106, 447-452. [Cross Ref]
- [4]. Sorate, K.A.; Bhale, P.V. Biodiesel properties and car framework similarity issues. Recharge. Maintain. Energy Rev. 2015, 41, 777-798. [CrossRef]
- [5]. Brown, W.; Poon, T. Benzene and Its Derivatives. In Introduction to Organic Chemistry, fourth ed.; John Wiley and Sons, Inc.: Hoboken, NJ, USA, 2011; pp. 316-322, 334-341.
- [6]. Saluja, R.K.; Kumar, V.; Sham, R. Dependability of biodiesel-A survey. Recharge. Maintain. Energy Rev. 2016, 62, 866-881. [CrossRef]
- [7]. Avase, S.A.; Srivastava, S.; Vishal, K.; Ashok, H.V.; Varghese, G. Impact of Pyrogallol as an Antioxidant on the Performance and Emission Characteristics of Biodiesel Derived from Waste Cooking Oil. Procedia Earth Planet. Sci. 2015, 11, 437-444. [CrossRef]
- [8]. Karavalakis, G.; Hilari, D.; Givalou, L.; Karonis, D.; Stournas, S. Capacity security and maturing impact of biodiesel mixes treated with various cell reinforcements. Energy 2011, 36, 369-374. [Cross Ref]
- [9]. Mittelbach, M.; Schober, S. The impact of cancer prevention agents on the oxidation dependability of biodiesel. J. Am. Oil Chem. Soc. 2003, 80, 817-823. [Cross Ref]
- [10]. Varatharajan, K.; Pushparani, D.S. Screening of cancer prevention agent added substances for biodiesel powers. Recharge. Maintain. Energy Rev. 2018, 83, 2017-2028. [Cross Ref]

- [11]. Mohd Hafizil Mat Yasin, Rizalman Mamat, and Liyana Amer Shah. Fuel Physical Characteristics of Biodiesel Blend Fuels with Ahmad Fitri Yusop, Rafidah Rahim, Amir Aziz Alcohol as Additives, Malaysian Technical Universities Conference on Engineering & Technology 2012, MUCET 2012, Procedia Engineering, Volume 53, 2013, Pages 701-706.
- [12]. Orkun Ozener, Levent Yuksek, Alp Tekin Ergenc, Muammer Ozkan Effects of soybean biodiesel on a DI diesel engine performance, emission and combustion characteristic, Fuel (2012) 10:081.
- [13]. Amin Talebian-Kiakalaieh, Nor Aishah Saidina Amin, Hossein Mazaheri. A review on novel processes of biodiesel production from waste cooking oil, Applied Energy, Applied Energy 104(2013) 683-710, Page 1-20.
- [14]. H. An, W.M. Yang, A. Maghbouli, J. Li, S.K. Chou, K.J. Chua., 2013. Performance, combustion and emission characteristics of biodiesel derived from waste cooking oils, Applied Energy 112, p.497.
- [15]. S.V.A.R. Sastry, Ch.V. Ramachandra Murthy. Prospects of biodiesel for future energy security, Elixir Chem. Engg. 53 (2012) 12029-12034
- [16]. Marta Serrano, Abderrahim Bouaid, Mercedes Martínez, José Aracil. Oxidation stability of biodiesel from different feedstocks: Influence of commercial additives and purification step, Fuel 113 (2013) 50-58.
- [17] Polavka J, Paligová J, Cvengroš J, Šimon P. Oxidation stability of methyl esters studied by differential thermal analysis and rancimat. J Am Oil Chem Soc 2005; 82:519-24.
- [18]. Conceição MM, Dantas MB, Rosenhaim R, Fernandes Jr VJ, Santos IMG, Souza AG. Evaluation of the oxidative induction time of the ethyl castor biodiesel. J. Therm. Anal. Calorim. 2009; 97:643-6.
- [19]. Walter W. Focke, Isbe van der Westhuizen, A.B. Lofte Grobler, Khomotso T. Nshoane, Judysynthetic K. Reddy, Adriaan S. Luyt. The effect of antioxidants on the oxidative stability of biodiesel, Fuel 94 (2012) 227-233

