

COMBUSTION AND EMISSION ANALYSIS OF HYDROGEN GAS WITH JATROPHA OIL USING TOROIDAL PISTON

Submitted in partial fulfilment of the requirements for the award of

Bachelor of Engineering degree in

Mechanical Engineering

by

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DEPARTMENT OF MECHANICAL ENGINEERING

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SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited with grade “A” by NAAC

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **VENKATA SIVA KAVARTHAPU (Reg No: 37150208)** and **SYED SIRAJ (Reg No: 37150191)** who carried out the project entitled “**COMBUSTION AND EMISSION ANALYSIS OF HYDROGEN GAS WITH JATROPHA OIL USING TOROIDAL PISTON**” under our supervision from October 2020 to April 2021

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DECLARATION

We, **VENKATA SIVA KAVARTHAPU (Reg No: 37150208)** and **SYED SIRAJ (Reg No: 37150191)** hereby declare that the Project Report entitled **“COMBUSTION AND EMISSION ANALYSIS OF HYDROGEN GAS WITH JATROPHA OIL USING TOROIDAL PISTON”** is a record of an original work done by us under the guidance of **Dr. J. HEMANANDH, M.E., Ph.D.**, at **SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY** is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in Mechanical Engineering.

DATE: 17-04-2021

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ABSTRACT

Diesel engines have been the main source of fuel for many generations across wide varieties of locomotives. But we can't ignore the fact that it produces most of the pollutants like CO, HC and NO_x in the environment. As it is a fossil fuel the resources are depleting and there is a need for a search for an alternate fuel. Biodiesel can be an alternative for fossil fuels. Biodiesel is a form of fuel that is derived from plants and animals and contains long-chain fatty acids of esters. By using toroidal piston there can be a reduction of CO and HC emission. By injecting hydrogen into the engines, the H-C ratio of the fuel can be increased and also makes the combustion mixture to be premixed before combustion and reduces the emission of hydrocarbons, carbon monoxides. In this paper the combustion analysis of jatropha Biodiesel which is extracted from jatropha curcas by transesterification process as the fuel with blends is tested in a diesel engine with the injection of hydrogen and is compared to standard diesel fuel.

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LIST OF ABBREVIATIONS

CO	Carbon Monoxide
CO ₂	Carbon Dioxide
NO _x	Nitrous Oxides
UHC	Unburnt Hydrocarbons
BTE	Brake Thermal Efficiency
BSFC	Brake Specific Fuel Consumption
H/C	Hydrogen by Carbon
HRR	Heat Release Rate
P-θ	Pressure Angle
ppm	Parts Per Million
LPM	Litres Per Minute
NaOH	Sodium Hydroxide
kJ/kg	Kilo Joule per Kilogram
kg/m ³	Kilogram per meter cube
kJ/kg K	Kilo Joule per Kilogram Kelvin
EGR	Exhaust Gas Recirculation
TCP	Toroidal cavity piston
HCP	Hemispherical cavity piston
H ₂	Hydrogen
TP J20	Toroidal piston 20% blended jatropha biodiesel
TP	Toroidal piston

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CHAPTER 1

INTRODUCTION

Nowadays as the population is increasing a greater number of vehicles are being used in our daily life. Due to this the amount of fossil fuel required is increasing. As we are using more and more amount of fossil fuel there is a possibility that it may not be available for the future generations. So, scientists are searching for an alternate fuel that has the properties of fuels and produces less pollution when compared to fossil fuels.

1.1 BIODIESEL:

Bio diesel is a friendly and alternative fuel that is derived from fats of animals and vegetable oil and can be an alternative for fossil fuel. The importance for Bio diesel has been increasing in the recent days as the pollution that is caused by the fossil fuels has been becoming a greater threat to the environment. Bio diesel can be prepared from any natural oil with fats when combined with alcohol such as methanol and ethanol. Bio diesel helps in reducing CO, HC, CO₂ and smoke due to soot free and complete combustion. Bio diesel is also safe as it has high flash point and is also bio-degradable and non-toxic. But the cost of preparing biodiesel from the raw fats of plants and animals is higher when compared it with fossil fuel. In our research we found that the biodiesel that is prepared from jatropha curcas is cost efficient and requires less amount of work.

1.2 JATROPHA CURCAS:

Jatropha caucis is a small oleaginous fruit bearing from Euphorbiaceous that thrives in warm weather and can grow in barren soil. Bio diesel from jatropha oil is extracted by reducing the fatty acids in Jatropha oil and then by using Transesterification process.

1.3 TRANSESTERIFICATION:

Transesterification process is the process of converting fats of plants and animals into esters and esters and glycerol. A catalyst is used in order to increase the yield and reaction rate. For high yield of Bio diesel to be obtained alkaline catalyzed transesterification process is a very promising option. For every 100 liters

of oil, we use we can obtain about 90 liters of Bio diesel from jatropha oil. By using the blends of Biodiesel, the brake specific fuel consumption is higher when compared to diesel and there is a reduction in CO₂ and HC emissions when compared with diesel.

1.4 TOROIDAL PISTON:

Toroidal piston is a type of circular-sectioned piston with a torus shaped chamber in between the circular section. By using toroidal piston instead of standard hemispherical piston for Bio diesel there is an increase in the brake thermal efficiency and the heat release rate of the fuel and there is a reduction in the brake specific fuel consumption, CO, HC emission. With the usage of toroidal piston there can be an improvement in the fuel atomization, reduction in the fuel droplet size and increased cylinder wall temperature.

1.5 HYDROGEN:

Hydrogen is clean source of fuel. It is an eco-friendly, non-toxic and odorless fuel. It is a renewable fuel which on combustion with oxygen releases water as the by-product. On using hydrogen, a smaller No of pollutants like carbon-monoxide and carbon-dioxide are releases into the atmosphere. As hydrogen is having high flammability, requires low ignition energy and high flame speed so it can be used as a secondary fuel for releasing less amount of pollutants and for good combustion.

CHAPTER 2

LITERATURE SURVEY

1. Fossil fuels such as gasoline, coal, and natural gas are the primary sources of energy. Fossil fuels account for 80% of global energy consumption. There is a search for sustainable and clean alternative fuels due to the rise in emissions emitted by fossil fuels. Biodiesel is one of the alternatives that can be considered. Biodiesel can be made from the fatty acids or natural oil from plants or animals when chemically coming them with methanol or ethanol. Biodiesel holds the promise of various advantages in terms of energy security, economics, agricultural expansion, and pollution reduction.
2. Diesel engine parameters are more compatible with running on straight diesel than biodiesel and biodiesel blends in general. To achieve better performance with biodiesel in conventional diesel engines, optimising operating conditions as well as piston bowl geometry is critical. So toroidal piston bowl geometry is used instead of traditional hemispherical piston bowl geometry. Improved fuel atomization, reduced fuel droplet size, increased cylinder temperature, and increased squish, swirl, and turbulence kinetic energy during combustion could all be attributed to using toroidal piston bowl geometry instead of hemispherical piston bowl geometry.
3. Biodiesel of jatropha, algae, waste cooking oil and palm were taken at the blends of B10 and B20 and the emission of CO, HC, NO_x and CO₂ emission are taken and are compared with diesel. When compared to diesel fuel, CO, HC, and smoke emissions were lower for the four biodiesel types (Jatropha, algae, palm, and waste cooking oil) mixtures B10 and B20. When compared to diesel fuel and other biodiesel fuels, CO emissions from biodiesel mixes B10 and B20 made from waste cooking oil were higher. NO_x emission in biodiesels is higher when compared to diesel.
4. The engine performance and emission analysis of crude jatropha biodiesel of blends B5, B10 and B20 are made by using transesterification and are compared to standard diesel at a range of 1100 to 2500 rpm. The results show that BSFC for Jatropha biodiesel blends is usually higher than pure diesel, despite the fact that the brake power output and engine torque produced by Jatropha biodiesel blends are

lower than diesel. In addition, when compared to diesel fuel, the use of all Jatropha biodiesel blends shows a trend to decrease CO₂ and HC emissions, while NO_x emissions are higher.

5. Biodiesel is a non-petroleum-based fuel that has a mass-based energy content of about 12% less than petroleum-based diesel fuel. Transesterification process is used for making biodiesel from jatropha oil. The process uses Jatropha oil and methanol as its primary raw materials, with NaOH serving as the catalyst. Based on our findings, the bio diesel extracted produces an annual yield of 90 litres for every 100 litres of oil.

6. Hydrogen has a high flame speed, requires little ignition energy, has a very small quenching thickness, and has a wide range of flammability, all of which pose a significant safety risk. The hydrogen assisted diesel combustion overcomes the disadvantage of the base diesel engine's lean operation, which is difficult to ignite and results in lower power output, fewer misfires, and improved combustion and emissions. The brake thermal efficiency improved as the percentage replacement of hydrogen increased, but the results were reversed at higher load conditions and at low load conditions. Complete combustion resulted in lower emissions of HC, CO₂, and CO, but NO_x increased due to the higher combustion temperature.

7. From this study and the fact that hydrogen fuel has a high self-ignition temperature, it can be concluded that hydrogen fuel is better suited for use in gasoline engines. The compression ratio can be improved further by adding hydrogen to gasoline in specific proportions to improve the engine's efficiency and performance. Many studies have shown that depending on the amount of hydrogen added to the fuel, the engines benefit in terms of performance and fuel consumption.

8. A detailed investigation of performance and emission analysis is done on jatropha biodiesel of blends from B10 to B100 at 1500 rpm on a single cylindered water-cooled diesel engine. It has been determined that Jatropha oil can be used directly or in combination with diesel fuel in diesel engines. The use of Jatropha oil can improve performance while lowering smoke emissions.

9. One of the most promising alternatives for conserving fossils is to use biodiesel made from Jatropha oil through a transesterification process. In the presence of an acid catalyst, the oil derived from jatropha is converted into methyl

ester (Biodiesel). It has been proven that Jatropha oil can be used to make biodiesel. The results of the experiment show that alkaline catalysed transesterification is a promising area of study for large-scale biodiesel production.

10. From this study, the toroidal cavity piston operation, the brake thermal efficiency of neat corn oil biodiesel and its blends was increased, while CO, HC, and smoke emissions were reduced at full load. When comparing diesel fuel with HCP operation to corn oil methyl ester and its diesel blends with toroidal piston operation, NOx emissions were marginally higher.

11. With a higher percentage of Jatropha oil in the blends, CO₂ emissions increased. CO emissions from blends, on the other hand, were slightly higher than those from diesel, the higher the amount of Jatropha oil in the blend, the higher the CO emissions.

12. Biodiesel is the most recent development in the quest for a substitute for current fossil fuels, which are depleting at a faster pace than they are being replaced. There is a risk that the engines over efficiency would be reduced as a result of this, which may be in terms of combustion, output, or emission. Injecting hydrogen into the inlet manifold with ambient air will increase the engine's efficiency and combustion characteristics, but exhaust emissions, fuel handling, and engine configuration alternatives are major concerns. In the event of increased NOx emissions, it is recommended that exhaust gas recirculation be used.

13. The blends like J2.6, J20, J50 and diesel were used in a single cylinder direct injection engine. The results are like J2.6 releases less amount of carbon dioxide when compared to other blends. Diesel releases less amount of carbon monoxide when compared to rest of the fuels. The brake thermal efficiency, brake power increases with increase in the blends while brake specific fuel consumption reduces with the increase in the blends.

14. By mixing jatropha curcas oil with diesel, the high viscosity of the oil, which has been regarded as a possible alternative fuel for compression ignition (C.I.) engines, was reduced. Because of the lower viscosity of the jatropha oil, the real fuel consumption and exhaust gas temperature were decreased. With blends containing up to 50% jatropha oil, acceptable thermal efficiencies of the engine were achieved. It has been determined that 40–50% of jatropha oil can be substituted for

diesel without any engine modifications based on its properties and engine test performance.

15. A significant advancement in the science and engineering that underpins the production of combustion engines and turbines are studied.

16. Efficiency and emission parameters were found to be very similar to mineral diesel for lower blend concentrations when the engine was run on Jatropha oil (preheated and blends). However, efficiency and emissions were found to be slightly inferior at higher blend concentrations.

17. When the engine was fuelled with Jatropha oil instead of gasoline, the BTE (brake thermal efficiency) was lower and the BSEC (brake specific energy consumption) was higher. When the temperature of the fuel inlet was raised, the BTE increased and the BSEC decreased.

18. Biodiesel is manufactured from jatropha oil using an acid catalyst (5% H_2SO_4) and methanol during the esterification and transesterification processes. The transesterification process lasted 2 hours, with a 6:1 molar ratio of methanol to oil and a sodium hydroxide concentration of 0.7 weight percent of oil. The methyl ester of jatropha oil yielded about 97%. The properties of the biodiesel mostly depend on its nature and the preparation process.

19. From this study, B25 performs similarly to diesel, while B100 has lower brake thermal efficiency, owing to its higher viscosity than diesel. The brake thermal performance for biodiesel and its blends was found to be marginally higher than that of diesel fuel at measured load conditions and there was no disparity between the biodiesel and its blended fuels efficiencies.

20. The performance of the engine was improved by injecting hydrogen peroxide at all fractions along with diesel, and the temperature of the exhaust gas was found to be reduced fairly. In addition, the performance of the engine has been improved by advancing the injection timing by five degrees for both diesel and hydrogen peroxide blends.

21. As compared to diesel fuel, measurements revealed that the mixed fuel H_2/O_2 decreased brake specific fuel consumption (BSFC) the most, by 12.6 percent, Meanwhile, the emission of air pollutants decreased by 9.5 percent for HCs, 7.2

percent for CO, and 4.4 percent for CO₂, but increased by 9.9 percent for NO_x with H₂/O₂.

22. Hydrogen was supplied to the intake manifold through a mixer before entering the combustion chamber to investigate the combustion characteristics of this dual fuel. The use of hydrogen in the combustion chamber decreased the amount of diesel used. The efficiency of the system decreases as the load decreases. With hydrogen, cylinder pressure drops, but slightly rises at higher loads.

23. The diesel engine's intake port was used to pump hydrogen. Due to mixture formation and higher flame speed of hydrogen gas, an improvement in brake specific fuel consumption and brake thermal performance is observed for all engine loads. CO, UHC, and SOOT emissions significantly decreased for hydrogen gas as an additional fuel at all loads, with a greater decrease in SOOT emissions at higher loads, according to the results.

24. The results of co-combustion of biodiesel and hydrogen in a compression-ignition internal combustion engine showed that biodiesel can be replaced with hydrogen up to a 38 percent energetic share. The presence of hydrogen in the co-combustion process changes the combustion phases and reduces the combustion time. The increase in the H₂ share resulted in an increase in engine thermal performance. Soot emissions have been significantly reduced as a result of the reduction in the diffusion combustion process.

25. The amount of H₂ and the amount of EGR were both different. Temperature and pressure were measured. When it comes to NO_x emissions, which is a big concern when using a diesel engine and is observed in the process. The H₂ delivered to the engine had a positive impact on engine capacity, as shown by increased pressure and temperature. It did, however, display a negative impact on NO_x emissions. When H₂ is supplied, it is recommended that EGR be used to monitor NO_x emissions.

CHAPTER 3

AIM AND SCOPE

3.1 AIM:

The Aim of the project is to investigate the performance and emission analysis of biodiesel with hydrogen in dual fuel mode and comparing it with standard diesel with hydrogen and without hydrogen by using toroidal piston head. For this experiment Jatropha biodiesel is prepared by using transesterification process and is blended with diesel to make J20 Jatropha Biodiesel.

3.2 SCOPE:

The scope of the project is to look at the combustion and emission analysis of the fuels by using J20 jatropha biodiesel and Diesel as the primary fuel and Hydrogen as the secondary fuel and comparing them in order to find out the best fuels that releases less pollutants and gives good combustion results.

CHAPTER 4

METHOD AND MATERIALS

Jatropha Bio diesel is prepared from jatropha oil by using transesterification process. First seeds were taken from jatropha caucus and jatropha oil is extracted from the jatropha caucus seeds.

4.1 TRANSESTERIFICATION PROCESS:

Then the fatty acids present in the jatropha oil is checked. The fatty acids are more than the desired level required. So, the fatty acids are being reduced to the desired level of 1%. 21 ml of jatropha oil is taken and poured in the conical flask is heated up to a temperature of 50°C. Methanol was taken and is purified by heating it in a round bottom flask. NaOH pellets were taken and weighed to about 0.5g. Using potassium hydroxide, methanol and NaOH pellets potassium methoxide is prepared. Potassium methoxide is heated to a temperature of 60°C in a beaker to meet the temperature of jatropha oil. Then the jatropha oil and the potassium methoxide solutions were mixed and stirred vigorously for 50 minutes and is allowed to settle the solution for 24 hours. The outcome is the combination of jatropha Bio diesel and glycerol. The glycerol is heavier than the jatropha Bio diesel so it settled down in the bottom and the jatropha Bio diesel floats in the top. The jatropha Bio diesel is separated from glycerol by using warm water and is taken away in a separate beaker. The excess amount of water in jatropha Bio diesel is separated by evaporation process. A liter of Bio diesel(B100) is prepared by using the above process. Then blends like J20 are made with standard diesel and Bio diesel. The characteristics of jatropha biodiesel is shown in the table 1. The process of transesterification is shown in the fig 4.



Fig.1: Blends of Jatropha curcas biodiesel

Table 1: characteristics of jatropha biodiesel with different blends

Characteristics	JB20	JB100	BS VI Standards of diesel	Standard diesel (ASTM D975)
Kinematic viscosity @ 40° in CST	1.59	4.7	2.0 – 4.5	4.1
Flash point	56	110	35	51 min
Fire point	66	121	-	-
Gross calorific value KJ/Kg	41308	36543	-	43012
Density in Kg/m ³	863	910	810-845	860-900



Fig.2: Bomb calorimeter



Fig.3: Digital Bomb calorimeter

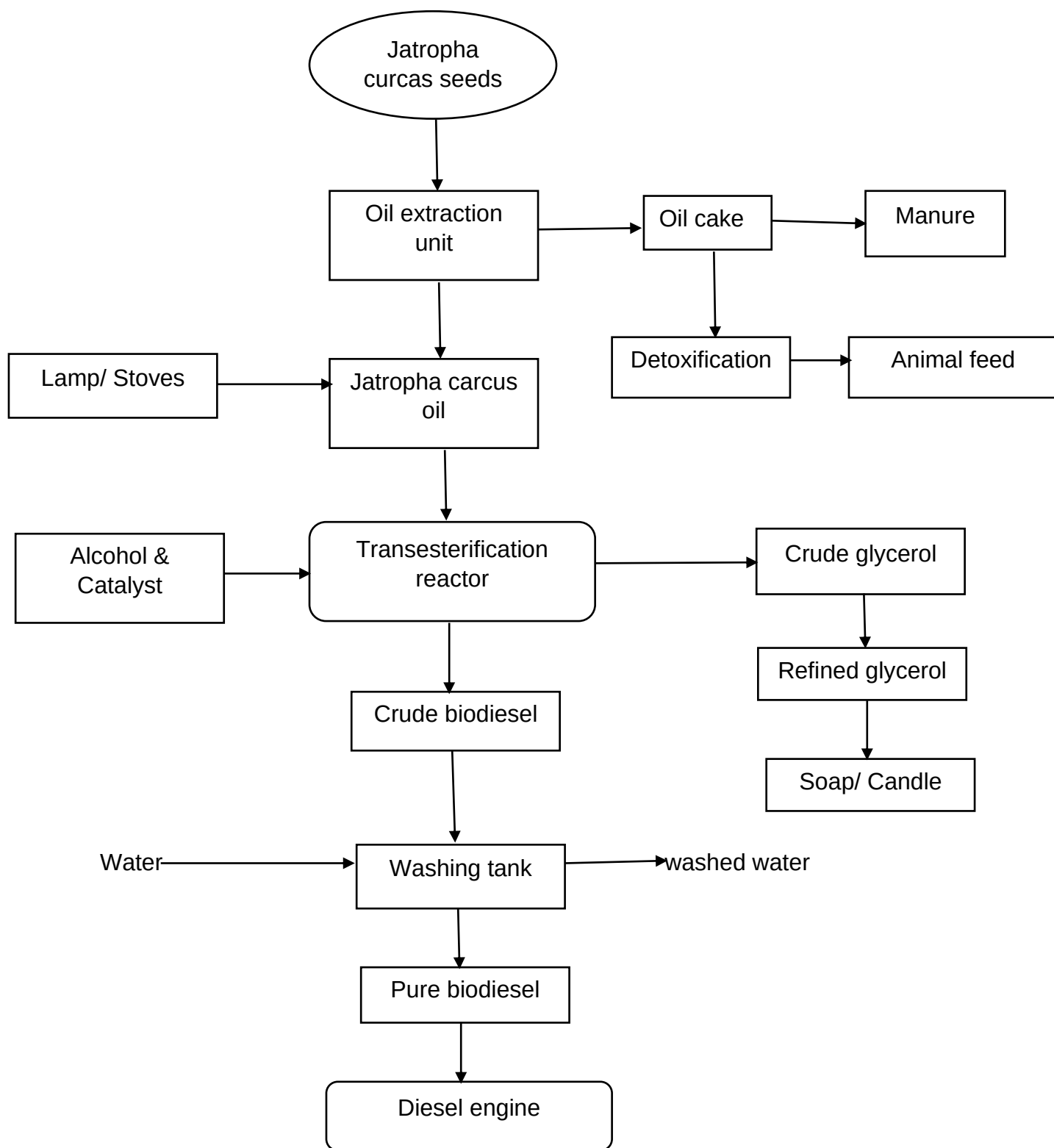


Fig.4: Flow chart of transesterification process

4.2 ENGINE SPECIFICATIONS:

The IC engine taken for the experiment is a Kirloskar TV1 with a power of 3.76KW at an rpm of 1500rpm. The specifications of the engine are 1-cylinder diesel

engine with 4 strokes at constant speed and water-cooled engine with a stroke length of 110mm, Cylinder Bore of 87.50mm, swept volume of 661cc, Connecting rod length of 234mm. And with a Compression ratio of 17.50. The specifications of the engine is shown in table 2.

Table 2: Specifications of engine

Product	Engine test setup 1 cylinder, 4stroke, Diesel (Computerized)
Product code	224
Engine	Make Kirloskar, Model TV1, Type 1 cylinder, 4 stroke Diesel, water cooled, power 5.2 kW at 1500 rpm, stroke 110 mm, bore 87.5mm. 661cc, CR 17.5
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
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	Type two wire, input RTD PT100, Range 0-100 °C, I/p Thermocouple, Range 0-1200 °C, O/P 4-20mA
Load indicator	Digital, Range 0-50 Kg, Supply 230VAC
Load sensor	Load cell, type strain gauge, range 0-50kg
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

4.3 COMBUSTION PARAMETERS:

Specific Gas Constant (kJ/kg K): 1.00, Air Density (kg/m³): 1.17, Adiabatic Index: 1.41, Polytrophic Index: 1.07, No of Cycles: 10, Cylinder Pressure Reference: 6, Smoothing 2, TDC Reference: -6.

4.4 PERFORMANCE PARAMETERS:

Orifice Diameter (mm): 20.00, Orifice Coefficient of Discharge: 0.60, Dynamometer Arm Length (mm): 185, Fuel Pipe diameter (mm): 12.40, Ambient Temp. (Degree C): 27, Pulses Per revolution: 360, Fuel Type: Diesel, Fuel Density (Kg/m³): 830, Calorific Value of Fuel (KJ/kg): 42500.

4.5 WHY HYDROGEN GAS IS USED:

In our research the blends that are used are mostly from B5 to B20. Above B20 the combustion of air-fuel mixture is inappropriate and causes knocking effect in the engine.

To overcome this problem hydrogen is used as a secondary fuel as it has high flame speed, requires low ignition energy and has wide flammability and it is also used to over-come the drawback of lean operations and results in the reduction of misfires, improving combustion and emission. The properties of hydrogen gas are shown in table 3.

Table 3: Properties of hydrogen gas

Molecular weight	2.01 kg/k mol
Density	0.0838 kg/m ³
Flash Point	585°C
Flame speed	270-325 cm/s
Octane Number	130
Cetane Number	-
F/A stoichiometric	34.3

4.6 EXPERIMENTAL APPARATUS:

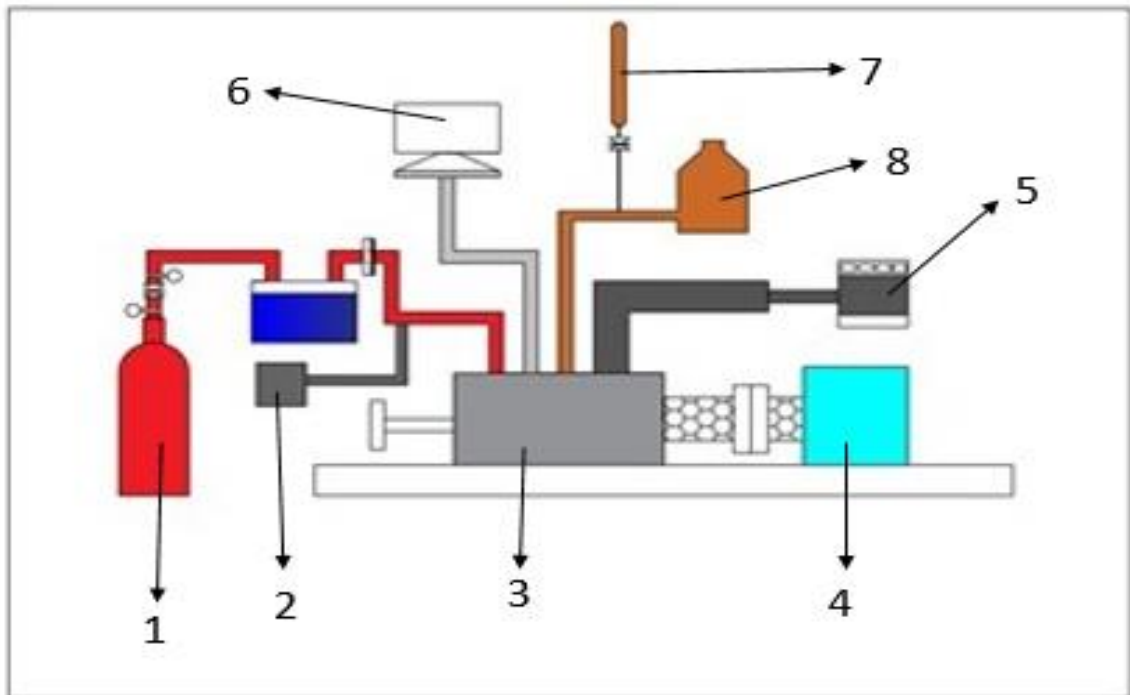


Fig.5: Schematic representation of engine

1. Hydrogen Cylinder
2. Intake air chamber
3. Single Cylinder 4 Stroke Cylinder
4. Eddy Current Dynamometer
5. Smoke analyzer
6. Monitor
7. Burette
8. Fuel tank

4.6.1. Hydrogen Cylinder:

Cylinder consisting of hydrogen gas shown in fig 6.



Fig 6: Hydrogen Cylinder

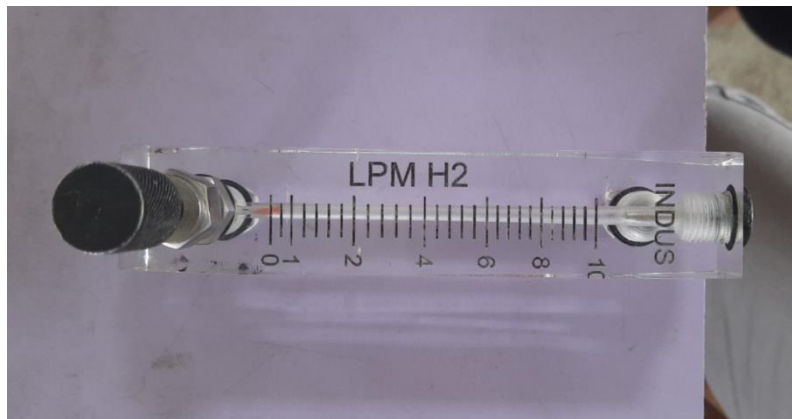


Fig 7: Rotameter

4.6.2. Intake Air Chamber:

The air is taken into the chamber to allow it for combustion.

4.6.3. Eddy current Dynamometer:

The eddy current dynamometer is used to supply load on the engine and is shown in fig 8.

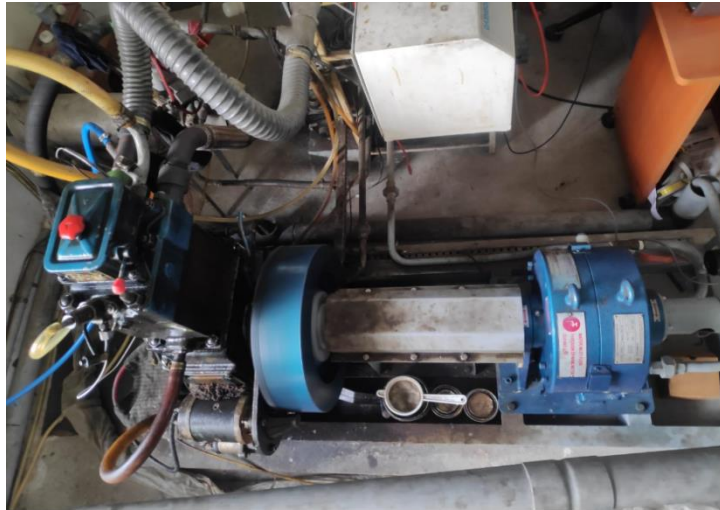


Fig 8: Eddy current dynamometer connected to the engine.

4.6.4. Single Cylinder 4 stroke Engine:

The diesel engine used to run the engine which is a single cylinder and 4 stroke engines. Toroidal piston is used inside the diesel engine to run the experiment. The engine is shown in fig 11 and toroidal piston inside the cylinder is shown in fig9.

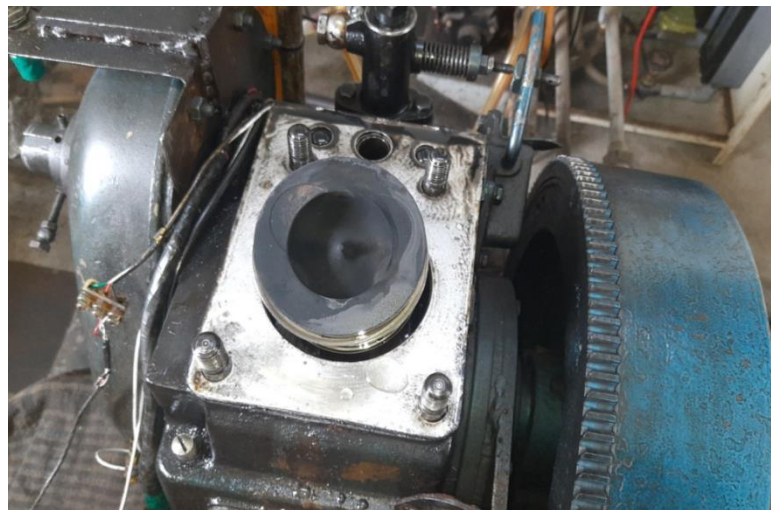


Fig 9: Toroidal piston inside the engine

4.6.5. Smoke Analyzer:

Used to analyze the exhaust smoke from the engine after combustion. The smoke meter is shown in fig 10.

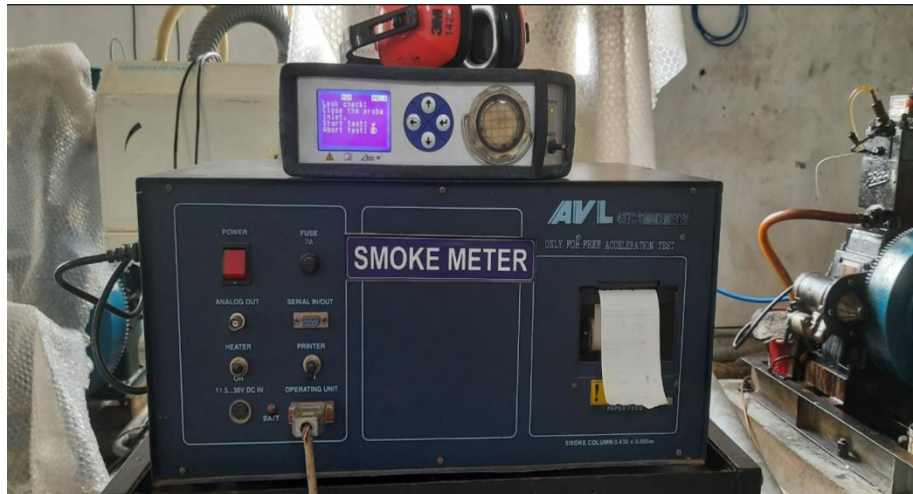


Fig.10: Smoke Analyzer

4.6.6. Monitor:

To observe the performance and combustion of the engine at every angle of the crankshaft.

4.6.7. Burette:

It is used to calculate the brake specific fuel combustion of the fuel.

4.6.8. Fuel Tank:

Is used to store the fuel before combustion.

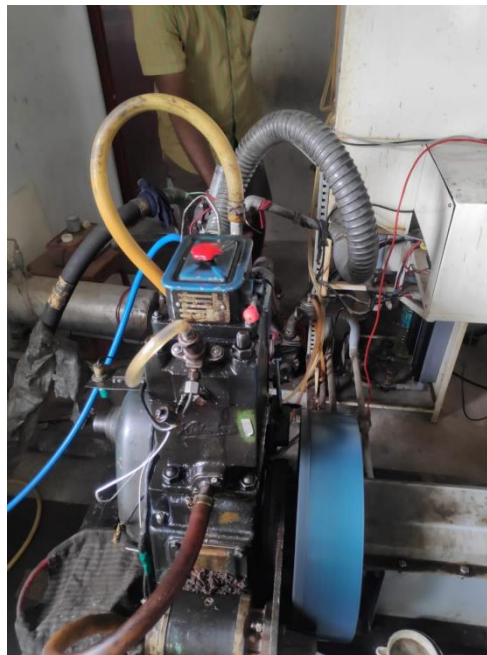


Fig.11: Diesel Engine

4.7 EXPERIMENTAL PROCEDURE:

The above apparatus is combined as shown in the experimental setup. The hydrogen gas is taken from the hydrogen cylinder and the fuel is taken from the fuel tank, the hydrogen gas is allowed to pass through the spark arrester (or) flame arrester and then through the flow meter where the flow rate is adjusted to 4 LPM (liters per minute). The hydrogen is then mixed with the fresh air at the inlet air chamber and is mixed with the fuel that is taken from the fuel tank with the injection pressure of 200 bar into the cylinder. The water-cooled eddy current dynamometer is used to apply different loads on the engine. The smoke and gas analyzer are used to collect the emission data from the engine. The Engine Soft Software is used to evaluate the power, efficiencies, fuel consumptions and heat release. In the same way data is taken by using different fuels like diesel, J20(jatropha Bio diesel) hydrogen and standard diesel without using hydrogen. The data like CO, HC, O₂, Smoke and NO_x emissions are taken. The time taken for the of 10ml of fuel is used to calculate the brake specific fuel consumption is also taken.

CHAPTER 5

RESULTS AND DISCUSSIONS

5.1 EMISSION ANALYSIS

5.1.1 Carbon Monoxide (CO) Emission:

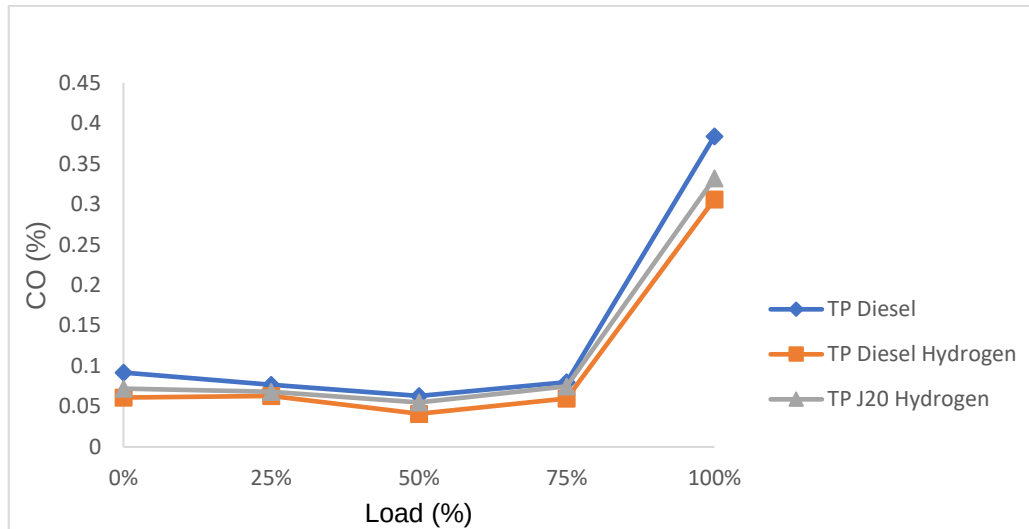


Fig 12: Variation of CO Emissions with respect to diesel

From fig 12, we can notice that as there is an almost steady emission of CO until 75% Load but there is a sudden increase in the CO emission at 100% of load. At 100% load the Diesel with 4 LPM of Hydrogen is emitting less amount of CO and Toroidal piston Diesel is releasing high amount of CO. There is a decrease of 12.5% of CO emission of Toroidal piston Diesel with Hydrogen when compared to Toroidal piston Diesel. The reason for the decrease in the CO emission is due to the addition of Hydrogen which causes low emission of carbon particles into the atmosphere which causes the reduction in the carbon emission.

5.1.2 Unburnt Hydro Carbon (UHC) Emission:

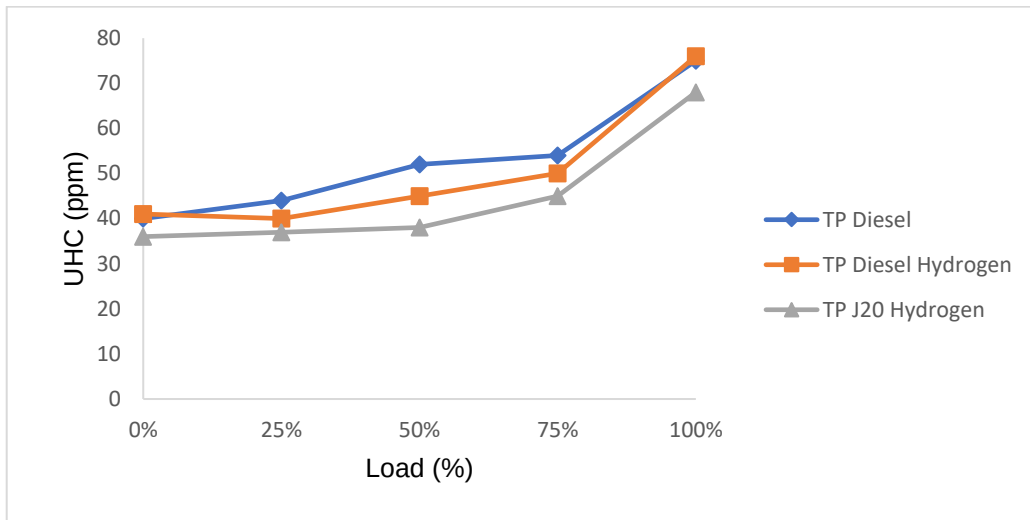


Fig 13: Variation of Unburnt HC Emissions with respect to diesel

From fig 13, there is a steady increase in the HC emissions with the increase in the load. At 100% load Diesel with 4LPM is releasing more amount of HC emissions and TP JB20 jatropha biodiesel with Hydrogen is releasing less No of hydrocarbons into the atmosphere. There is a decrease of 11.1% of HC with TP J20 jatropha biodiesel with Hydrogen when compared to Diesel with Hydrogen. As the cetane No in diesel is higher than Jatropha Bio diesel which is the main reason for over mixed fuel the unburnt hydrocarbons are released more from the diesel when compared it to Jatropha

5.1.3 Carbon Dioxide (CO₂) Emission

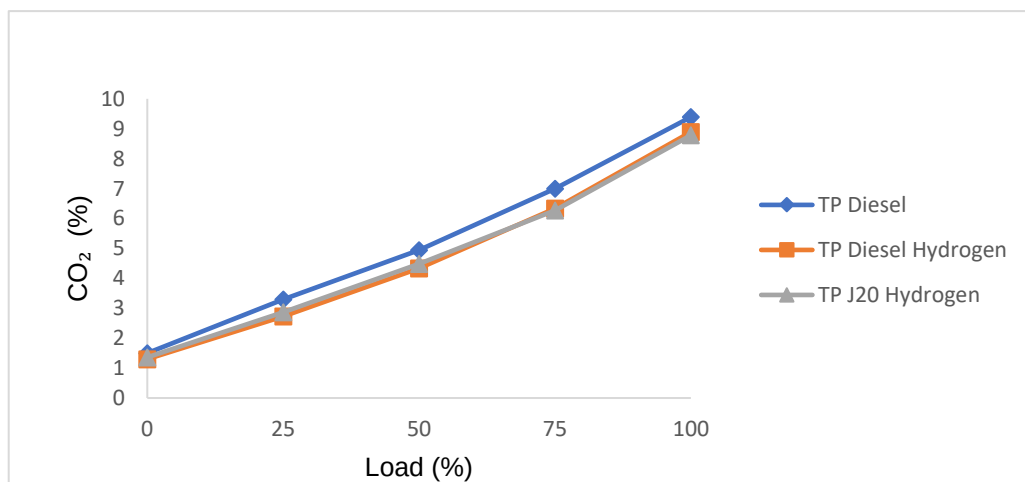


Fig 14: Variation of CO₂ Emissions with respect to diesel

From fig 14, we can notice that with the increase in the load in the cylinder there is an increase in the emission of CO₂. Among all the fuels at 100% of load to the engine TP Diesel is emitting more amount of CO₂ and 30% blended Jatropha Bio diesel is emitting less amount of CO₂. There is an increase of 10.6% of CO₂ emission in TP Diesel when compared it to TP J20 Jatropha Bio diesel. The reason for the reduction of CO₂ emission is the introduction of Hydrogen during the combustion which emits less amount of carbon particles making the combustion cleaner.

5.1.4 Nitrous Oxide (NO_x) Emission

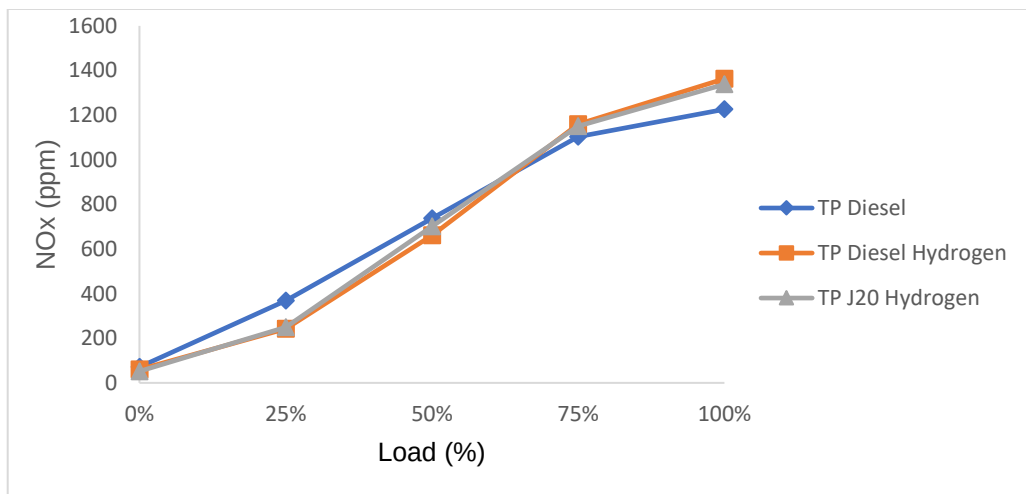


Fig 15: Variation of NO_x Emissions with respect to diesel

From fig 15, with the increase in the load there is an increase in the NO_x emission. TP Diesel with hydrogen is emitting high amount of NO_x and TP Diesel is releasing less amount of NO_x. There is an increase of 11.1% of NO_x content in TP Diesel when compared it to TP Diesel with hydrogen. The reason for the increase in the NO_x content during the emission is the NO_x emission depends upon the cylinder wall temperature and oxygen content in the fuel. So as the hydrogen is introduced during combustion the cylinder wall temperature is increased so the NO_x emission also increases.

5.1.5 Opacity Smoke Analysis

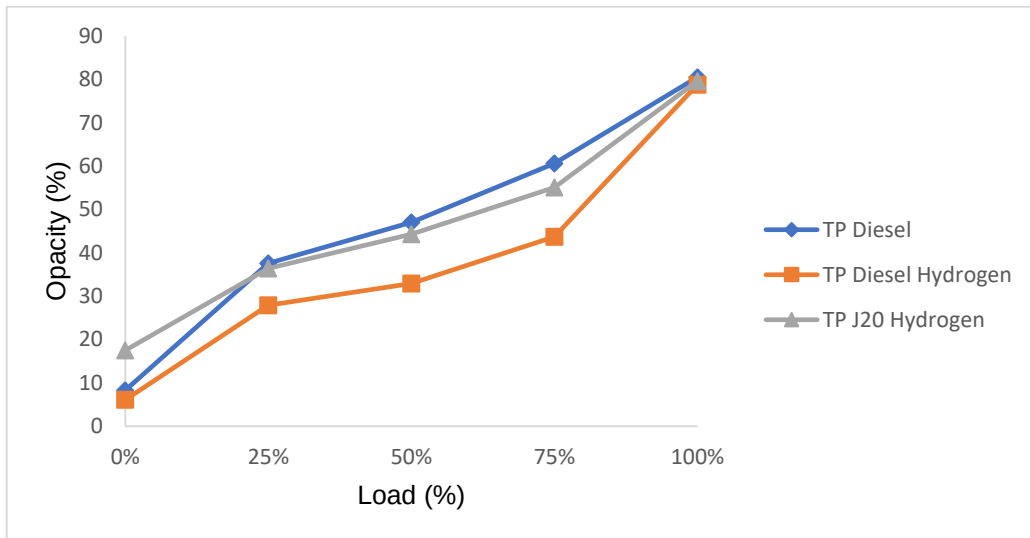


Fig 16: Variation of Opacity Smoke with respect to diesel

From fig 16, we can observe that at the opacity of the fuel increases with the increase in the load. Normally with diesel there will be an incomplete combustion, so the opacity of the diesel is high. There is an increase of 10.1% of soot in TP Diesel when compared it to TP Diesel with hydrogen. The less amount of opacity is observed in TP Diesel with Hydrogen, the reason is due to the use of hydrogen during the combustion process which is clean fuel which means less amount of soot is released into the atmosphere, so less opacity is seen in Diesel with hydrogen.

5.2 COMBUSTION ANALYSIS:

5.2.1 Brake Thermal Efficiency

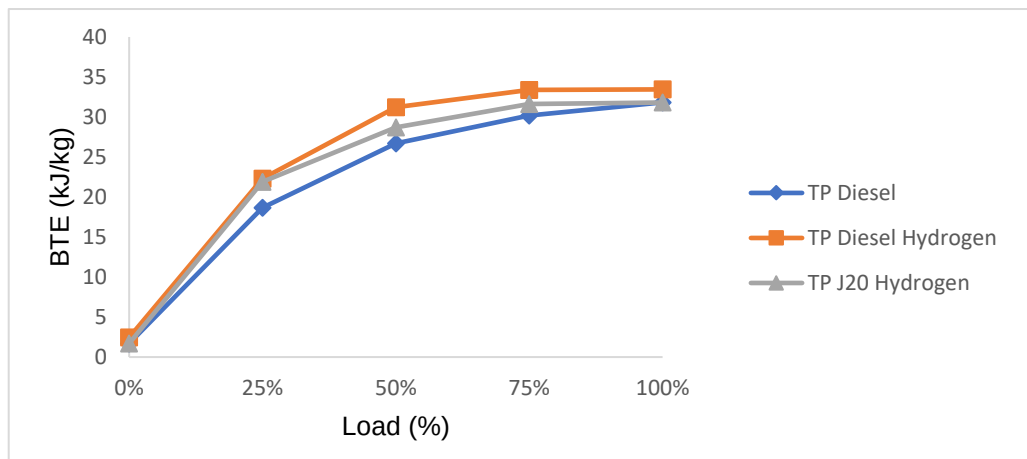


Fig 17: Variation of Brake Thermal Efficiency with respect to diesel

From fig 17, there is an increase in the brake thermal efficiency with increase in the load. The maximum brake thermal efficiency is seen in TP J20 jatropha biodiesel and minimum is seen in TP Diesel. The reason for this due to high viscosity and density of Bio diesel, and its results longer ignition delay and it leads to incomplete combustion. In our study BTE increased in fuels with blends in Bio diesel then comparison with pure diesel. It's seems that the test conducted with addition of hydrogen and test conducted without addition of hydrogen shows similar results. Highest No of blends will give's the highest amount of BTE.

5.2.2 Pressure Angle

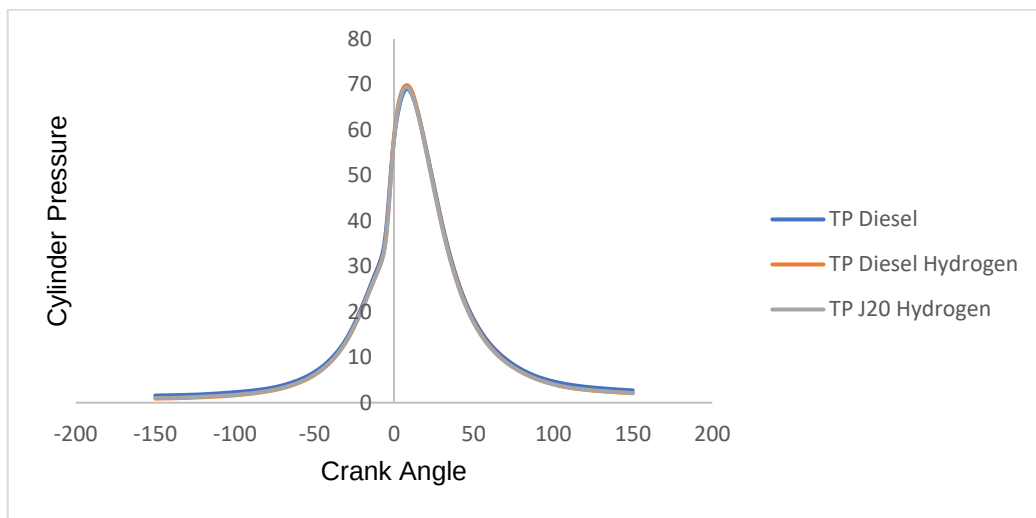


Fig 18: Variation of Pressure Angle with respect to diesel

From fig 18, In combustion process it is the one of the most important parameters used for analysis in combustion, P- θ curves helps to shows the mechanical loads of in-cylinder which occurs as result of combustion of fuel by crank angle. In above graph shows the pressure variation for different fuels. In cylinder pressure Angle (P- θ) seems to be similar for almost for other fuel tests and abnormal combustion characteristics like high pressure raise rates were not seen. The reason for this is lower heating values than diesel fuel. In our experiment, when Bio diesel is enriched with hydrogen, due to this higher flame velocity, cylinder pressure is increased.

5.2.3 Heat Release Rate Diagram

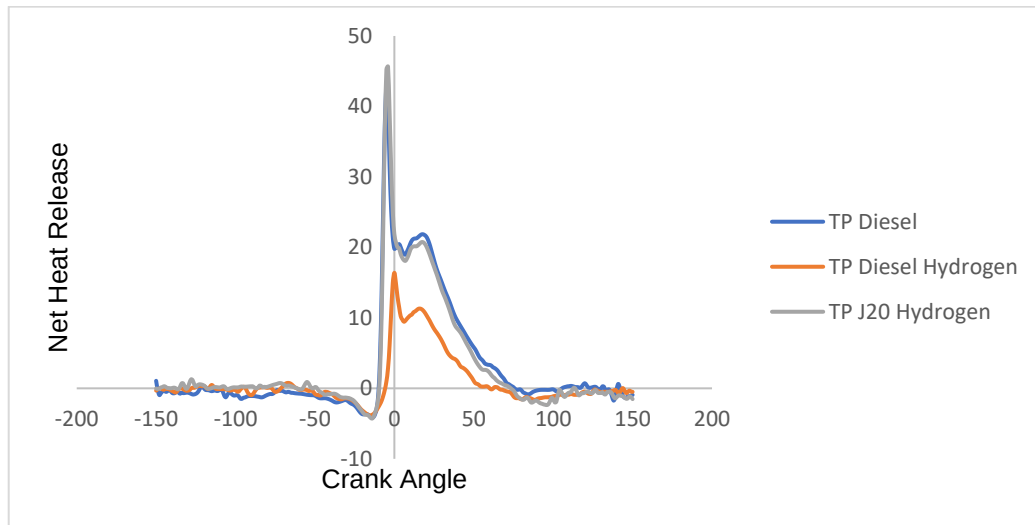


Fig 19: Variation of Heat Release Rate with respect to diesel

From fig 19, It shows that the heat release rate diagram from -150 to +150 degrees of crank angle. Normally during our research, the heat release rate of blended biodiesel is less when compared to diesel. But due to the introduction of hydrogen during the combustion process, we have seen that the heat release rate of J20 biodiesel is almost equal that of the heat release rate of diesel with hydrogen. The reason is due to the introduction of hydrogen which have high flame velocity and instantaneous combustion of hydrogen which brings the heat release rate of JB30 Jatropha biodiesel comparably equal to diesel with hydrogen.

5.2.4 Brake Specific Fuel Consumption

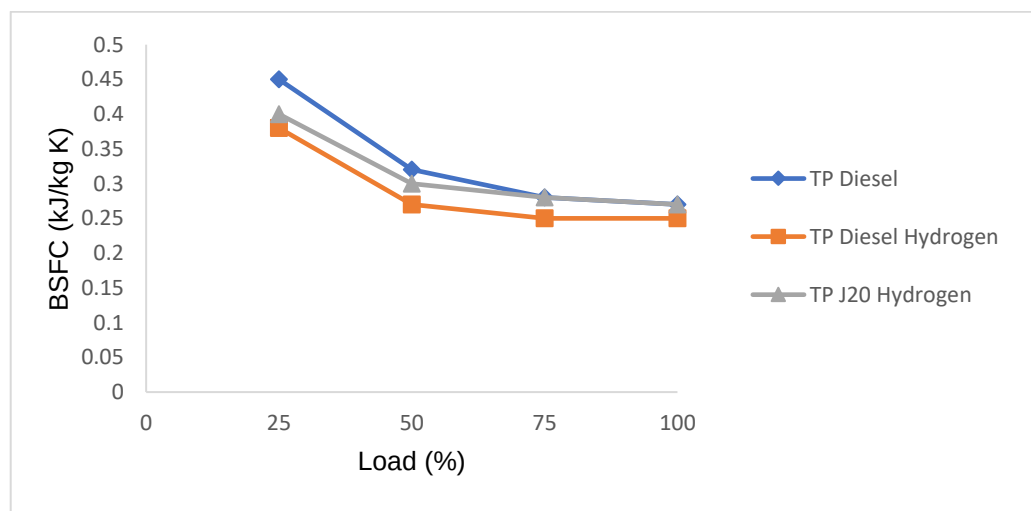


Fig 20: Variation of Brake Specific Fuel Consumption with respect to diesel

From fig 20, the brake specific fuel combustion of the fuels is decreasing when there is an increase in the load. The lowest brake specific fuel consumption is given by TP Diesel with hydrogen at 100% load. BSFC of fuel decreases with the increase in the load, as we introduce hydrogen into the combustion chamber the combustion rate is increased as the fuel is burn to maximum extent. So, the BSFC decreases with increase in load.

CHAPTER 6

SUMMARY AND CONCLUSION

6.1 SUMMARY

In Summary, as the fossil fuels are depleting and we are moving toward a global energy crisis the alternate fuels like biofuels can be used to overcome this energy crisis. Use of biofuels with hydrogen is good for the environment as they release a smaller number of pollutants when compared to petroleum-based fuels and also gives good combustion results when compared to diesel.

6.2 CONCLUSION

In this study the jatropha biodiesel is produced from Jatropha oil by using NaOH as catalyst using transesterification process and is used as a primary fuel in the combustion along with Hydrogen as secondary fuel with the use of toroidal piston head. The results were like as follows:

- ❖ In CO emission graph, diesel with hydrogen releases less amount of CO and diesel releases high amount of CO emission.
- ❖ In HC emission graph, J20 JATROPHA biodiesel releases less amount of HC emission and Diesel with hydrogen releases high amount of HC emission.
- ❖ In CO₂ emission graph, JB30 releases less amount of CO₂ emission and Diesel releases high amount of CO₂ emission.
- ❖ In NO_x emission graph, JB30 JATROPHA biodiesel releases high amount of NO_x emission and Diesel releases less amount of NO_x.
- ❖ In opacity graph, Diesel with hydrogen is seen with less amount of opacity while compared to less amount of opacity.
- ❖ In Load vs BTE graph Diesel with hydrogen releases has high amount of brake thermal efficiency where as JB20 JATROPHA biodiesel has low amount of brake thermal efficiency.
- ❖ In P-θ Diagram all the fuels have almost the same amount of pressure at every crank angle.
- ❖ In heat release rate diagram, the heat release of blends of JATROPHA oil is almost equal to Diesel.

- ❖ In Brake specific fuel combustion diagram, the brake specific fuel combustion of fuel decreases with increase in the load.

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Sentence

INTRODUCTION Nowadays as the population is increasing a greater number of vehicles are being used in our daily life. Due to this the amount of fossil fuel required is increasing. As we are using more and more amount of fossil fuel there is a possibility that it may not be available for the future generations. So, scientists are searching for an alternate fuel that has the properties of fuels and produces less pollution when compared to fossil fuels.

1.1 Biodiesel: Bio diesel is a friendly and alternative fuel that is derived from fats of animals and vegetable oil and can be an alternative for fossil fuel. The importance for Bio diesel has been increasing in the recent days as the pollution that is caused by the fossil fuels has been becoming a greater threat to the environment. Bio diesel can be prepared from any natural oil with fats when combined with alcohol such as methanol and ethanol. Bio diesel helps in reducing CO, HC, CO₂ and smoke due to soot free and complete combustion. Bio diesel is also safe as it has high flash point and is also bio-degradable and non- toxic. But the cost of preparing biodiesel from the raw fats of plants and animals is higher when compared it with fossil fuel. In our research we found that the biodiesel that is prepared from jatropha curcas is cost efficient and requires less amount of work.

1.2 Jatropha Curcas: Jatropha caucus is a small oleaginous fruit bearing from Euphorbiaceous that thrives in warm weather and can grow in barren soil. Bio diesel from jatropha oil is extracted by reducing the fatty acids in Jatropha oil and then by using Transesterification process.

1.3 Transesterification: Transesterification process is the process of converting fats of plants and animals into esters and esters and glycerol. A catalyst is used in order to increase the yield and reaction rate. For high yield of Bio diesel to be obtained alkaline catalyzed transesterification process is a very promising option. For every 100 liters of oil, we use we can obtain about 90 liters of Bio diesel from jatropha oil. By using the blends of Biodiesel, the brake specific fuel consumption is higher when compared to diesel and there is a reduction in CO₂ and

HC emissions when compared with diesel. 1.4 Toroidal piston: Toroidal piston is a type of circular-sectioned piston with a torus shaped chamber in between the circular section. By using toroidal piston instead of standard hemispherical piston for Bio diesel there is an increase in the brake thermal efficiency and the heat release rate of the fuel and there is a reduction in the brake specific fuel consumption, CO, HC emission. With the usage of toroidal piston there can be an improvement in the fuel atomization, reduction in the fuel droplet size and increased cylinder wall temperature.

1.5 Hydrogen: Hydrogen is clean source of fuel. It is an eco-friendly, non-toxic and odorless fuel. It is a renewable fuel which on combustion with oxygen releases water as the by-product. On using hydrogen, a smaller No of pollutants like carbon-monoxide and carbon-dioxide are releases into the atmosphere. As hydrogen is having high flammability, requires low ignition energy and high flame speed so it can be used as a secondary fuel for releasing less amount of pollutants and for good combustion.

LITERATURE SURVEY

1. Energy is one of the most vital resources for humanity's long-term survival. The energy crisis has now become one of the most pressing global issues we face. Fuels are extremely important because they can be burned to generate large quantities of energy. Fuels are used in many aspects of daily life, including the transportation of goods and people. Fossil fuels such as gasoline, coal, and natural gas are the primary sources of energy. Fossil fuels account for 80% of global energy consumption. There is a search for sustainable and clean alternative fuels due to the rise in emissions emitted by fossil fuels. Biodiesel is one of the alternatives that can be considered. Biodiesel can be made from the fatty acids or natural oil from plants or animals when chemically coming them with methanol or ethanol. Finally, biodiesel production is expected to spike in the coming years. Biodiesel holds the promise of various advantages in terms of energy security, economics, agricultural expansion, and pollution reduction.

2. Diesel engine parameters are more compatible with running on straight diesel than biodiesel and biodiesel blends in general. To achieve better performance with biodiesel in conventional diesel engines, optimising operating conditions as well as piston bowl geometry is critical. So toroidal piston bowl geometry is used instead of traditional hemispherical piston bowl geometry. Improved fuel atomization, reduced fuel droplet size, increased cylinder temperature, and increased squish, swirl, and turbulence kinetic energy during combustion could all be attributed to using toroidal piston bowl geometry instead of hemispherical piston bowl geometry.

3. Biodiesel of jatropha,

algae, waste cooking oil and palm were taken at the blends of B10 and B20 and the emission of CO, HC, NO_x and CO₂ emission are taken and are compared with diesel. When compared to diesel fuel, CO, HC, and smoke emissions were lower for the four biodiesel types (Jatropha, algae, palm, and waste cooking oil) mixtures B10 and B20. When compared to diesel fuel and other biodiesel fuels, CO emissions from biodiesel mixes B10 and B20 made from waste cooking oil were higher.

NO_x emission in biodiesels is higher when compared to diesel. 4. The engine performance and emission analysis of crude jatropha biodiesel of blends B5, B10 and B20 are made by using transesterification and are compared to standard diesel at a range of 1100 to 2500 rpm. The results show that BSFC for Jatropha biodiesel blends is usually higher than pure diesel, despite the fact that the brake power output and engine torque produced by Jatropha biodiesel blends are lower than diesel. In addition, when compared to diesel fuel, the use of all Jatropha biodiesel blends shows a trend to decrease CO₂ and HC emissions, while NO_x emissions are higher. 5. Biodiesel is a non-petroleum-based fuel that has a mass-based energy content of about 12% less than petroleum-based diesel fuel. Biodiesel is currently produced using a variety of techniques. Transesterification process is used for making biodiesel from jatropha oil. The process uses Jatropha oil and methanol as its primary raw materials, with NaOH serving as the catalyst. Bio diesel has been derived from jatropha oil. Based on our findings, the bio diesel extracted produces an annual yield of 90 litres for every 100 litres of oil. 6. The impact of hydrogen addition on diesel engine performance and emissions in dual fuel mode was investigated. It demonstrates that while the effect on diesel engines has a positive impact on emissions, the lack of power may be felt at high loads. Hydrogen has a high flame speed, requires little ignition energy, has a very small quenching thickness, and has a wide range of flammability, all of which pose a significant safety risk. However, this can be overcome by electrolysis-based hydrogen generation on board. Water electrolysis produces HHO gas, which is a mixture of hydrogen and oxygen. The hydrogen assisted diesel combustion overcomes the disadvantage of the base diesel engine's lean operation, which is difficult to ignite and results in lower power output, fewer misfires, and improved combustion and emissions. The brake thermal efficiency improved as the percentage replacement of hydrogen increased, but the results were reversed at higher load conditions and at low load conditions. Complete combustion

resulted in lower emissions of HC, CO₂, and CO, but NO_x increased due to the higher combustion temperature. 7. The effects of hydrogen as an extra fuel to internal combustion gasoline, diesel, and LPG engines on engine performance and exhaust emissions are explained. Engine power and torque are increased at most on petrol engines, while they are reduced on LPG and diesel engines, depending on the amount of hydrogen added to the fuel system. Based on the findings of these studies and the fact that hydrogen fuel has a high self-ignition temperature, it can be concluded that hydrogen fuel is better suited for use in gasoline engines. The compression ratio can be improved further by adding hydrogen to gasoline in specific proportions to improve the engine's efficiency and performance. Many studies have shown that depending on the amount of hydrogen added to the fuel, the engines benefit in terms of performance and fuel consumption. Furthermore, due to the structural properties of the engines, it has been determined that gasoline engines are more likely to benefit from hydrogen enrichment in terms of exhaust emissions and fuel consumption rates. 8. A detailed investigation of performance and emission analysis is done on jatropha biodiesel of blends from B10 to B100 at 1500 rpm on an single cylindered water cooled diesel engine. It has been determined that Jatropha oil can be used directly or in combination with diesel fuel in diesel engines. The use of Jatropha oil can improve performance while lowering smoke emissions. 9. One of the most promising alternatives for conserving fossils is to use biodiesel made from Jatropha oil through a transesterification process. In the presence of an acid catalyst, the oil derived from jatropha is converted into methyl ester (Biodiesel). It has been proven that Jatropha oil can be used to make biodiesel. The results of the experiment show that alkaline catalysed transesterification is a promising area of study for large-scale biodiesel production. 10. The influence of piston bowl geometry on the output and emission characteristics of a single cylinder diesel engine [hemispherical cavity piston (HCP) and toroidal cavity piston (TCP)]. Diesel and corn oil methyl ester, as well as their diesel blends, have been used. Different loading conditions have been investigated. The results showed that for toroidal cavity piston operation, the brake thermal efficiency of neat corn oil biodiesel and its blends was increased, while CO, HC, and smoke emissions were reduced at full load. When comparing diesel fuel with HCP operation to corn oil methyl ester and its diesel blends with toroidal piston operation, NO_x emissions were marginally higher. 11. As a substitute fuel for diesel engines, a non-edible vegetable oil was developed from Jatropha fruits, and its

usability was investigated as a pure oil and as a blend with petroleum diesel fuel. The blends like J10, J20, J50 and J80 were used. The results were like Up to J20 ratios, no major improvement in brake thermal efficiency or brake specific fuel consumption was observed. Higher blends, on the other hand, saw a 10% to 25% reduction in performance and fuel consumption. CO₂ emissions from blends were lower than diesel at low loads, but higher at high loads. With a higher percentage of Jatropha oil in the blends, CO₂ emissions increased. CO emissions from blends, on the other hand, were slightly higher than those from diesel, the higher the amount of Jatropha oil in the blend, the higher the CO emissions. 12. Biodiesel is the most recent development in the quest for a substitute for current fossil fuels, which are depleting at a faster pace than they are being replaced. There is a risk that the engines over efficiency would be reduced as a result of this, which may be in terms of combustion, output, or emission. Injecting hydrogen into the inlet manifold with ambient air will increase the engine's efficiency and combustion characteristics, but exhaust emissions, fuel handling, and engine configuration alternatives are major concerns. In the event of increased NO_x emissions, it is recommended that exhaust gas recirculation be used. 13. The blends like J2.6, J20, J50 and diesel were used in a single cylinder direct injection engine. The results are like J2.6 releases less amount of carbon dioxide when compared to other blends. Diesel releases less amount of carbon monoxide when compared to rest of the fuels. The brake thermal efficiency, brake power increases with increase in the blends while brake specific fuel consumption reduces with the increase in the blends. 14. By mixing jatropha curcas oil with diesel, the high viscosity of the oil, which has been regarded as a possible alternative fuel for compression ignition (C.I.) engines, was reduced. Blends of jatropha curcas oil and diesel in various proportions were prepared, analysed, and compared to diesel fuel. Because of the lower viscosity of the jatropha oil, the real fuel consumption and exhaust gas temperature were decreased. With blends containing up to 50% jatropha oil, acceptable thermal efficiencies of the engine were achieved. It has been determined that 40–50% of jatropha oil can be substituted for diesel without any engine modifications based on its properties and engine test performance. 15. A significant advancement in the science and engineering that underpins the production of combustion engines and turbines are studied. 16. The aim of the experiments was to see whether raising the fuel temperature (using waste heat from the exhaust gases) could reduce the viscosity of Jatropha oil and thus

eliminate its effect on the engine's combustion and emission characteristics. Efficiency and emission parameters were found to be very similar to mineral diesel for lower blend concentrations when the engine was run on Jatropha oil (preheated and blends). However, efficiency and emissions were found to be slightly inferior at higher blend concentrations. 17. The aim of this research is to minimise oil viscosity by heating it with exhaust gases before feeding it to the engine, as well as to investigate the effects of FIT (fuel inlet temperature) on engine efficiency and emissions using a dual fuel engine test rig with a properly built shell and tube heat exchanger. The heat exchanger was set up in such a way that the optimal FIT was achieved. When the engine was fuelled with Jatropha oil instead of gasoline, the BTE (brake thermal efficiency) was lower and the BSEC (brake specific energy consumption) was higher. When the temperature of the fuel inlet was raised, the BTE increased and the BSEC decreased. 18. Biodiesel is manufactured from jatropha oil using an acid catalyst (5% H_2SO_4) and methanol during the esterification and transesterification processes. The transesterification process lasted 2 hours, with a 6:1 molar ratio of methanol to oil and a sodium hydroxide concentration of 0.7 weight percent of oil. The methyl ester of jatropha oil yielded about 97%. The properties of the biodiesel mostly depend on its nature and the preparation process. 19. The output and exhaust emissions of a single cylinder water-cooled diesel engine using methyl-ester of Jatropha oil as fuel were assessed. The results showed that B25 performs similarly to diesel, while B100 has lower brake thermal efficiency, owing to its higher viscosity than diesel. The brake thermal performance for biodiesel and its blends was found to be marginally higher than that of diesel fuel at measured load conditions and there was no disparity between the biodiesel and its blended fuels efficiencies. 20. A four-stroke multi-cylinder, water-cooled compression ignition engine was used to test the effects of neat diesel and hydrogen peroxide/diesel blends. The main aim of this analysis is to see how well a diesel engine performs when hydrogen peroxide is injected as a blend with diesel at 2%, 5%, and 10% concentrations. The performance of the engine was improved by injecting hydrogen peroxide at all fractions along with diesel, and the temperature of the exhaust gas was found to be reduced fairly. In addition, the performance of the engine has been improved by advancing the injection timing by five degrees for both diesel and hydrogen peroxide blends. 21. The experiment was done by using H_2/O_2 to reduce the emission of pollutants of a heavy-duty Diesel engine at low steady state condition. As compared to Premium diesel fuel,

measurements revealed that the mixed fuel H_2/O_2 decreased brake specific fuel consumption (BSFC) the most, by 12.6 percent. Meanwhile, the emission of air pollutants decreased by 9.5 percent for HCs, 7.2 percent for CO, and 4.4 percent for CO_2 , but increased by 9.9 percent for NO_x with H_2/O_2 . 22. Hydrogen was supplied to the intake manifold through a mixer before entering the combustion chamber to investigate the combustion characteristics of this dual fuel. The use of hydrogen in the combustion chamber decreased the amount of diesel used. The efficiency of the system decreases as the load decreases. With hydrogen, cylinder pressure drops, but slightly rises at higher loads. 23. The effects of hydrogen addition on a four-cylinder, water-cooled diesel engine was studied in terms of engine efficiency and emissions. The diesel engine's intake port was used to pump hydrogen. Due to mixture formation and higher flame speed of hydrogen gas, an improvement in brake specific fuel consumption and brake thermal performance is observed for all engine loads. CO, UHC, and SOOT emissions significantly decreased for hydrogen gas as an additional fuel at all loads, with a greater decrease in SOOT emissions at higher loads, according to the results. 24. The results of co-combustion of biodiesel and hydrogen in a compression-ignition internal combustion engine showed that biodiesel can be replaced with hydrogen up to a 38 percent energetic share. The presence of hydrogen in the co-combustion process changes the combustion phases and reduces the combustion time. The increase in the H_2 share resulted in an increase in engine thermal performance. Soot emissions have been significantly reduced as a result of the reduction in the diffusion combustion process. 25. The operating parameters, such as cylinder pressure and gas temperature, were simulated using thermodynamic modelling. To find the solution, a finite different approach was used. The amount of H_2 and the amount of EGR were both different. Temperature and pressure were measured. When it comes to NO_x emissions, which is a big concern when using a diesel engine and is observed in the process. The H_2 delivered to the engine had a positive impact on engine capacity, as shown by increased pressure and temperature. It did, however, display a negative impact on NO_x emissions. When H_2 is supplied, it is recommended that EGR be used to monitor NO_x emissions.

METHOD AND MATERIALS First jatropha Bio diesel is prepared from jatropha oil by using transesterification process. 3.1 Transesterification: First seeds were taken from jatropha caucis and jatropha oil is extracted from the jatropha caucis seeds. Then

the fatty acids present in the jatropha oil is checked. The fatty acids are more than the desired level required. So, the fatty acids are being reduced to the desired level of 1%. 21 ml of jatropha oil is taken and poured in the conical flask is heated up to a temperature of 50°C. Methanol was taken and is purified by heating it in a round bottom flask. NaOH pellets were taken and weighed to about 0.5g. Using potassium hydroxide, methanol and NaOH pellets potassium methoxide is prepared. Potassium methoxide is heated to a temperature of 60°C in a beaker to meet the temperature of jatropha oil. Then the jatropha oil and the potassium methoxide solutions were mixed and stirred vigorously for 50 minutes and is allowed to settle the solution for 24 hours. The outcome is the combination of jatropha Bio diesel and glycerol. The glycerol is heavier than the jatropha Bio diesel so it settled down in the bottom and the jatropha Bio diesel floats in the top. The jatropha Bio diesel is separated from glycerol by using warm water and is taken away in a separate beaker. The excess amount of water in jatropha Bio diesel is separated by evaporation process. A liter of Bio diesel(B100) is prepared by using the above process. Then blends like B20 and B30 are made with standard diesel and Bio diesel.

3.2 Engine specifications: The IC engine taken for the experiment is a Kirloskar TV1 with a power of 3.76KW at an rpm of 1500rpm. The specifications of the engine are 1-cylinder diesel engine with 4 strokes at constant speed and water-cooled engine with a stroke length of 110mm, Cylinder Bore of 87.50mm, swept volume of 661cc, Connecting rod length of 234mm. And with a Compression ratio of 17.50. Product Engine test setup 1 cylinder, 4stroke, Diesel Product code 224 Engine Make Kirloskar, Model TV1, Type 1 cylinder, 4stroke Diesel, water cooled, power 5.2 kW at 1500 rpm, stroke 110 mm, bore 87.5mm. 661cc, CR 17.5 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 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 Type two wire, input RTD PT100, Range 0-100 °C, I/p Thermocouple, Range 0-1200 °C, O/P 4-20mA Load indicator Digital, Range 0-50 Kg, Supply 230VAC Load sensor Load cell, type strain gauge, range 0-50kg 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

3.3 Combustion Parameters: Specific Gas Constant (kJ/kg K): 1.00, Air Density (kg/m³): 1.17, Adiabatic Index: 1.41, Polytrophic Index: 1.07, No of Cycles: 10, Cylinder Pressure Reference: 6, Smoothing 2, TDC Reference: -6.

3.4 Performance Parameters: Orifice Diameter (mm): 20.00, Orifice Coefficient Of Discharge: 0.60, Dynamometer Arm Length (mm): 185, Fuel Pipe diameter (mm): 12.40, Ambient Temp. (Degree C): 27, Pulses Per revolution: 360, Fuel Type: Diesel, Fuel Density (Kg/m³): 830, Calorific Value of Fuel (KJ/kg): 42500.

3.5 Why hydrogen gas is used: In our research the blends that are used are mostly from B5 to B20. Above B20 the combustion of air-fuel mixture is inappropriate and causes knocking effect in the engine. To overcome this problem hydrogen is used as a secondary fuel as it has high flame speed, requires low ignition energy and has wide flammability and it is also used to overcome the drawback of lean operations and results in the reduction of misfires, improving combustion and emission.

3.6 Experimental Apparatus:

3.6.1. Hydrogen Cylinder: Cylinder consisting of hydrogen gas.

3.6.2. Intake Air Chamber: The air is taken into the chamber to allow it for combustion.

3.6.3. Eddy current Dynamometer: The eddy current dynamometer is used to supply load on the engine.

3.6.4. Single Cylinder 4 stroke Engine: The diesel engine used to run the engine which is a single cylinder and 4 stroke engines. Toroidal piston is used inside the diesel engine to run the experiment.

3.6.5. Smoke Analyzer: Used to analyze the exhaust smoke from the engine after combustion.

3.6.6. Monitor: To observe the performance and combustion of the engine at every angle of the crankshaft.

3.6.7. Burette: It is used to calculate the brake specific fuel combustion of the fuel.

3.6.8. Fuel Tank: Is used to store the fuel before combustion.

EXPERIMENTAL PROCEDURE The above apparatus is combined as shown in the experimental setup. The hydrogen gas is taken from the hydrogen cylinder and the fuel is taken from the fuel tank, the hydrogen gas is allowed to pass through the spark arrester (or) flame arrester and then through the flow meter where the flow rate is adjusted to 4 LPM (liters per minute). The hydrogen is then mixed with the fresh air at the inlet air chamber and is mixed with the fuel that is taken from the fuel tank with the injection pressure of 200 bar into the cylinder. The water-cooled eddy current dynamometer is used to apply different loads on the engine. The smoke and gas analyzer are used to collect the emission data from the engine. The

Engine Soft Software is used to evaluate the power, efficiencies, fuel consumptions and heat release. In the same way data is taken by using different fuels like diesel, JB20(jatropha Bio diesel) and JB30 with hydrogen and standard diesel without using hydrogen. The data like CO, HC, O₂, Smoke and NO_x emissions are taken. The time taken for the of 10ml of fuel is used to calculate the brake specific fuel consumption is also taken.

RESULTS AND DISCUSSIONS

5.1 Emission Analysis

5.1.1 Carbon Monoxide Emission

From the figure 2, we can notice that as there is an almost steady emission of CO until 75% Load but there is a sudden increase in the CO emission at 100% of load. At 100% load the Diesel with 4 LPM of Hydrogen is emitting less amount of CO and Toroidal piston Diesel is releasing high amount of CO. There is a decrease of 12.5% of CO emission of Toroidal piston Diesel with Hydrogen when compared to Toroidal piston Diesel. The reason for the decrease in the CO emission is due to the addition of Hydrogen which causes low emission of carbon particles into the atmosphere which causes the reduction in the carbon emission.

5.1.2 Hydro-Carbon Emission

From the figure 3, there is a steady increase in the HC emissions with the increase in the load. At 100% load Diesel with 4LPM is releasing more amount of HC emissions and TP JB20 jatropha biodiesel with Hydrogen is releasing less No of hydrocarbons into the atmosphere. There is a decrease of 11.1% of HC with TP J20 jatropha biodiesel with Hydrogen when compared to Diesel with Hydrogen. As the cetane No in diesel is higher than Jatropha Bio diesel which is the main reason for over mixed fuel the unburnt hydrocarbons are released more from the diesel when compared it to Jatropha

5.1.3 Carbon dioxide Emission

From the figure, we can notice that with the increase in the load in the cylinder there is an increase in the emission of CO₂. Among all the fuels at 100% of load to the engine TP Diesel is emitting more amount of CO₂ and 30% blended Jatropha Bio diesel is emitting less amount of CO₂. There is an increase of 10.6% of CO₂ emission in TP Diesel when compared it to TP J20 Jatropha Bio diesel. The reason for the reduction of CO₂ emission is the introduction of Hydrogen during the combustion which emits less amount of carbon particles making the combustion cleaner.

5.1.4 NO_x Emission

From the figure, with the increase in the load there is an increase in the NO_x emission. TP Diesel with hydrogen is emitting high amount of NO_x and TP Diesel is releasing less amount of NO_x. There is an increase of 11.1% of NO_x content in TP Diesel when compared it to TP Diesel with hydrogen. The reason for the increase in the NO_x

content during the emission is the NO_x emission depends upon the cylinder wall temperature and oxygen content in the fuel. So as the hydrogen is introduced during combustion the cylinder wall temperature is increased so the NO_x emission also increases.

5.2 Combustion Analysis:

5.2.1 Opacity Smoke Analysis From the above graph, we can observe that at the opacity of the fuel increases with the increase in the load. Normally with diesel there will be an incomplete combustion, so the opacity of the diesel is high. There is an increase of 10.1% of soot in TP Diesel when compared it to TP Diesel with hydrogen. The less amount of opacity is observed in TP Diesel with Hydrogen, the reason is due to the use of hydrogen during the combustion process which is clean fuel which means less amount of soot is released into the atmosphere, so less opacity is seen in Diesel with hydrogen.

5.2.2 Brake Thermal Efficiency From the graph there is an increase in the brake thermal efficiency with increase in the load. The maximum brake thermal efficiency is seen in TP J20 jatropha biodiesel and minimum is seen in TP Diesel. The reason for this due to high viscosity and density of Bio diesel, and its results longer ignition delay and it leads to incomplete combustion. In our study BTE increased in fuels with blends in Bio diesel then comparison with pure diesel. It's seems that the test conducted with addition of hydrogen and test conducted without addition of hydrogen shows similar results. Highest No of blends will give's the highest amount of BTE.

5.2.3 Pressure Angle In combustion process it is the one of the most important parameters used for analysis in CP, CP curves helps to shows the mechanical loads of in-cylinder which occurs as result of combustion of fuel by crank angle. In above graph shows the pressure variation for different fuels. In cylinder pressure ($p-\theta$) seems to be similar for almost for other fuel tests and abnormal combustion characteristics like high pressure raise rates were not seen. The reason for this is lower heating values than diesel fuel. In our experiment, when Bio diesel is enriched with hydrogen, due to this higher flame velocity, cylinder pressure is increased.

5.2.4 Heat Release Rate Diagram Figure shows that the heat release rate diagram from -150 to +150 degrees of crank angle. Normally during our research, the heat release rate of blended biodiesel is less when compared to diesel. But due to the introduction of hydrogen during the combustion process, we have seen that the heat release rate of J20 biodiesel is almost equal that of the heat release rate of diesel with hydrogen. The reason is due to the introduction of hydrogen which have high flame velocity and instantaneous combustion of hydrogen which brings the heat release rate of JB30 Jatropha biodiesel comparably

equal to diesel with hydrogen. 5.2.5 Brake Specific Fuel Consumption From the above graph, the brake specific fuel combustion of the fuels is decreasing when there is an increase in the load. The lowest brake specific fuel consumption is given by TP Diesel with hydrogen at 100% load. BSFC of fuel decreases with the increase in the load, as we introduce hydrogen into the combustion chamber the combustion rate is increased as the fuel is burn to maximum extent. So, the BSFC decreases with increase in load.

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