Effect of Fuel Injection Pressure on Combustion Characteristics of CI Engine Using Alternative Fuels

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***Abstract*: The depletion, growing call for and fee of the petroleum promoted widespread studies worldwide on opportunity power sources for internal combustion engines. There had been numerous researches which screen the significance of research on biodiesel rather gas to a diesel gas. It has established that biodiesel is one of the promising renewable, alternative and environmentally friendly bio fuels that can be used in diesel engine with little or no modification in the engine. The stringent emission legal guidelines, depletion of fossil fuels and relation of fuels with authorities' policies have compelled the world to find alternatives to fossil fuels.**

Numerous vegetable oils suitability has been investigated to be used in inner combustion engines. The outcomes of various fuels at the performance traits of engines have been drastically pronounced. The high viscosity and low volatility of those greens oils are the essential hassle for his or her use within the diesel engines. However use of various biodiesels in an engine consequences in variability in the engine performance and emission because of physical and chemical characteristics of fuel. The impact of these physio-chemical residences on gas deliver device consisting of gas pump and gasoline filter have already been suggested.

In this work an test is made to improve the combustion traits of the engine fueled with biodiesel (Palm Stearin Methyl Ester B20 & Animal Tallow methyl EasterB15). Hence a detailed research is finished at the underlying combustion and warmth launch traits. The experimental work is performed on four Stork, single cylinder, water cooled and DI stationary diesel engine. In this paintings Bsfc (Brake particular gasoline intake) and thermal efficiency are computed for exceptional in cylinder pressure and height warmness release rate.

***Index Terms*: biodiesel, physio-chemical, Bsfc, Ester B20, Liquefied Natural Gas (LNG)**

I. INTRODUCTION

India is one of the fastest growing international locations with a strong monetary boom, which multiplies the call for for transportation in many fields. Fuel consumption is directly proportionate to this demand. India depends mainly on imported fuels because of lack of fossil gasoline reserves and it has a notable impact on economic system. India has to look for an alternative to preserve the increase charge. Bio-diesel is a promising alternative for our Diesel desires. With sizable vegetation and land availability, absolutely bio-diesel is a possible supply of fuel for Indian situations. Recent research and research have made it feasible to extract bio-diesel at economical charges and portions. The combo of Bio-diesel with fossil diesel has many benefits like discount in emissions, increase in efficiency of engine, higher Cetane rating, lower engine put on, low fuel consumption, discount in oil consumption and so forth. It can be seen that the efficiency of the engine increases through the utilization of Bio-diesel. This could have a exceptional effect on Indian economy.

Diesel engine performs a dominant function inside the area of strength, propulsion and energy. The diesel engine is a sort of inner combustion engine, greater in particular it's far a compression ignition engine, in which the gas ignited completely via the high temperature created by compression of the air-gas combination. The engine operates the usage of the diesel cycle. The engine is greater efficient than the petrol engine, for the reason that spark –ignition engine consumes extra fuel than the compression –ignition engine. The gasoline injection gadget is the maximum important thing within the running of CI engine. The engine performance, strength output, economy and so on is substantially dependent on the effectiveness of the gasoline injection system. The injection gadget has to perform the crucial responsibility of initiating and controlling the combustion manner. The overall performance and emission traits of diesel engines relies upon on different factors like gas quantity injected, gasoline injection timing, fuel injection strain, shape of combustion chamber, position and size of injection nozzle hole, gas spray sample, air swirl and so on. The fuel injection gadget in a right away injection diesel engine is to gain a excessive diploma of atomization for better penetration of gas with the intention to make use of the full air price and to sell the evaporation in a totally short time and to acquire better combustion efficiency. A huge variety of studies have shown that biodiesel is one of the promising renewable, alternative and environmentally pleasant bio fuels that can be utilized in diesel engine with very little modification in the engine. The stringent emission legal guidelines, the depletion of fossil fuels and relation of fuels with politics have forced the world to discover alternatives to fossil fuels. Numerous vegetable oil esters (biodiesel) have been investigated for use in internal combustion engines and had been proven to have higher ability to reduce CO2 emission. The outcomes of different fuels at the performance characteristics of engines were appreciably mentioned. The common engine parameters on which consequences had been quantified encompass: The effects of those physio-chemical properties on gasoline deliver system which include gas pump, gas filter out and air-fuel blending cylinder have already been suggested. To enhance the performance and emission characteristics of the engine running with biodiesel and to understand the results of physical properties of the fuel at the engine performance and emissions a detailed Investigation is required at the underlying

combustion and warmth release characteristics. The warmth launched and Resulting strain and temperature fields affect the overall performance and emission traits maximum however maximum of the researchers up to now have correlated the overall performance and emission characteristics of biodiesel in opposition to test parameters consisting of biodiesel fraction combination, engine-velocity, engine load, injection timing, injection stress and engine compression ratio. However, there are only a few works which have been said on the engine combustion traits and heat launch phenomena corresponding to special biodiesels. Therefore, the goal of this observe is to research the performance, combustion traits and warmth release price phenomena of a compression ignition engine going for walks with biodiesel.

II TYPES OF ALTERNATIVE FUELS

Alternative fuels are fuels that aren't made from petroleum. There is much different kind of fuels that vehicles can use that aren't made from petroleum. Here are the different types of alternative fuels:

- Solar Energy
- Alcohols - ethanol and methanol
- Compressed Natural Gas (CNG) - natural gas under high pressure
- Electricity stored in batteries
- Hydrogen (considered a special gas)
- Liquefied Natural Gas (LNG) – natural gas that is very cold
- Liquefied Petroleum Gas (LPG) – called propane, it is hydrocarbon gas under low pressure
- Liquids made from coal – gasoline and diesel fuel that isn't made from petroleum
- Bio-diesel – diesel fuel made from plant oil or animal fat

II.1 Solar Cells Technologies

The US DOE announced that it'll make investments up to 13.7 million bucks over the subsequent 3 years in 11 tasks run via nine universities to paintings with an industry associate as a way to broaden superior solar photovoltaic (PV) production technique and merchandise. The projects contain gaining knowledge of approaches to make excessive overall performance sun cells extra effective by using the use of unique metals, alloys, and cellular designs. This will help transition the discoveries to the market region. The work being executed includes; to reduce bottle necks in the qualifications testing for concentrating solar cells, explode higher techniques of constructing crystalline sun cells, and explore sun cells built from thin movies of semi carrying out material, combine an natural (plastic) semiconductor with arrays of titanium dioxide nano tubes, and to create multi junction sun cells with the aid of depositing skinny layers of materials (amorphous silicon and indium phosphate) on to silicon sun cells. Multifunction solar cells convert more daylight into strength with the aid of using multiple layers of photovoltaic material, with every layer shooting a unique part of the solar spectrum, wherein because the current commercial multi junction sun cells have 3 lively layers. These efforts will bring about improving mobile efficiency from present 40% and additionally boom its lifestyles without maintenance.

II.2 Ethanol

Ethanol is sometimes referred to as "grain alcohol", is usually made inside the United States from corn. It also can make from biomass (organic substances) that include agricultural plants and waste (like rice straw), plant materials left from logging, and trash that consist of paper. Brazil is the biggest manufacturer within the world of ethanol and produces it from sugar cane. The alcohol determined in alcoholic drinks is also taken into consideration ethanol. However, the ethanol this is used for fuel is denatured, because of this additives are delivered to save you human consumption.

II.3 Methanol

Methanol is likewise referred to as "timber alcohol", may be made from many distinctive biomass resources like timber, as well as coal. However, nearly all methanol's are made from herbal fuel based totally on a cheaper manufacturing cost. Methanol is also very toxic and harmful if swallowed. Methanol need to not be confused with ethanol and as with fuel; pores and skin contest need to be averted, as it may pass via the pores and skin.

II.4 Compressed Natural Gas (CNG)

CNG is what many homes across the u . S . A . Prepare dinner with each and every day. A vehicle can also strength with CNG. Natural fuel comes from underground and is one of the maximum environmentally friendly fuels available. CNG is in the main made up of methane (ninety five%) with different five% being comprised of a combination of butane, propane, ethane and different trace gases. Methane is a hydrocarbon, meaning it is made up of hydrogen and carbon atoms. It's simple composition makes possible almost whole combustion. Cars, vans, buses and small vehicles commonly use natural fuel that has been compressed and saved in high-stress cylinders. Several car (together with Honda civic CGX and ford crown Victoria) are available that use CNG. A automobile that uses CNG and gasoline is known as bi-gasoline automobile.

II.5 Electricity saved batteries

Electricity stored batteries in electric vehicles had been round for a long term. In the early 1900s there have been more electric motors than there have been gas-powered automobiles considering gas was so high-priced. It become additionally tough to start the early engines. These early gas engines have been noisy and placed out lots of smoke, so electrics were a big hit! As new techniques of fuel production developed-thereby decreasing its price-a new invention known as a starter was invented, and electric automobiles started out to vanish away. Automobile groups are making cars run purifier and purifier. Ten of nowadays's automobiles could produce the same quantity of pollutants that would come from one vehicle simply 15 years in the past. Electric cars are still

being built and used and often are called zero-emission cars (ZEVs). These cars, for instance, account for approximately 2 percent of all vehicles offered.

II.6 Hydrogen gas cell cars

Hydrogen fuel mobile automobiles lead the race for gas-cell cars, and hydrogen cars also are taken into consideration to be ZEVs. Fuel-cellular automobiles flip hydrogen gasoline and oxygen into energy. The energy then powers an electric motor; just like the energy from batteries strength the motor of an electric powered automobile. To convey gaseous hydrogen on a vehicle, it need to be compressed. When compressed (three,000 kilos according to square inch) it must be saved in unique bins. This is similar to the manner compressed natural gasoline is saved on herbal gas-fueled cars. There are many exclusive methods of getting the hydrogen to the fuel cell, but maximum are extremely highly-priced. At gift, fuel-cellular motors are taken into consideration to be within the pre- prototype degree. This means there are few in lifestyles, although a few of the manufacturers have a prototype of 1 type or any other.

II.7 Hybrid vehicles

The phrase hybrid means some thing that is mixed together from things. A traditional hybrid is the Honda Insight, that could rise up to sixty eight mpg on the limited-access highway. The vehicle uses a small gasoline engine with an ultra skinny electric powered motor. Its primary energy comes from the gasoline engine, but it uses the electrical motor when it is accelerating or climbing hills. The electric motor does no longer want an external power supply for recharging. Regenerative braking recharges its batteries. That method strength from forward momentum is captured in the course of braking. This energy is then used to recharge the batteries. Most car companies are working on a hybrid or already have at the least one hybrid on the street today.

II.8 Liquefied Natural Gas (LNG)

Natural gasoline comes in 3 forms. One is the low- strain form you operate to cook dinner or warmth a home. It involves you in a pipe from the local gasoline employer. Another shape is compressed natural gas (CNG). This shape is compressed into excessive-strain cylinders to electricity a automobile or truck. It comes from special CNG gas stations. The third form is liquefied natural gas. LNG is made via refrigerating natural gas to condense it to a liquid. The liquid form is a whole lot extra dense that natural gasoline or CNG. It has more energy for the same amount of space it takes up. This makes LNG correct for vehicles to journey long distances. LNG is cooled to minus 260 ranges Fahrenheit beneath 0! Liquefied petroleum gasoline (LPG) - propane is what LPG is usually referred to as. That's due to the fact LPG is ordinarily made from propane. Actually, propane is made up of a mixture of propane and different types of hydrocarbon gases. Different batches of propane may additionally have slightly unique hydrocarbon molecules. These hydrocarbons are gases at room temperature, but turn to liquid whilst they're compressed. A propane tank is typically approximately two hundred kilos of strain. LPG-fueled engines pollute less than fuel and diesel engines. LPG commonly charges less than gas for the same quantity of electricity.

II.9 Liquids made from coals

Not all fuel comes from petroleum. There are ways to make fuel, diesel fuel, methanol and different fuels from coal. Other countries (inclusive of South Africa) were making gasoline and diesel fuel from coal for many years. These strategies may be used nowadays, but it's miles high-priced. It's cheaper to apply less expensive crude oil pumped from the floor beneath.

II.10 Biodiesel

Bio-diesel isn't always your ordinary vegetable oil and isn't always safe to swallow. However, biodiesel is considered biodegradable, so it is taken into consideration to be a great deal less dangerous to the environment if spilled. Biodiesel additionally has been proven to produce decrease tailpipe emissions than ordinary gasoline. The best element approximately biodiesel is that it's far made from flowers and animals, which can be renewable sources.

II.11 Eleven Bio fuels

The surroundings situation, excessive crude costs and growing dependency of overseas crude has drawn attention global closer to development of ethanol and bio-diesel as petro-gasoline replacement. This push is presently policy pushed in international locations like India, US, EU etc but Brazil is a extraordinary case. India transport sector is growing fast and this boom will preserve for a while extra. India is predominant sugar manufacturer with 17% share in world marketplace. Ethanol may be produced from molasses that's a byproduct in sugar manufacturing. There are adequate opportunities to supply ethanol and blend with diesel to keep petroleum product and import. The government has provided incentives to alter the sugar flora making them suitable to ethanol manufacturing. Biomass can be an attractive option for substitute of fossil fuels, through use of bio stable, liquid and gaseous fuels. Successful efforts have been made to provide alcohol, bio-diesel and biogas using different organic fabric.

III.EXPERIMENTAL SET-UP

The Kirloskar engine is one of the widely used engines in agriculture pump units, farm equipment and medium scale commercial functions. The setup includes a single cylinder, 4 strokes, naturally aspirated, water cooled Diesel engine related to eddy contemporary dynamometer. This eddy present day dynamometer is used for loading the engine. The engine is interfaced with Engine Soft Software for the size of combustion parameters. It is supplied with essential contraptions for combustion chamber strain and crank-attitude measurements. For the measurement of cylinder strain, a stress transducer is equipped on the engine cylinder head and a crank perspective encoder is used for the size of crank angle and TDC role. The stress and crank angle signals are fed to a facts acquisition card fitted with Pentium four private computer. The engine velocity is sensed and indicated through an inductive pick out up sensor along with a virtual rpm indicator that is a part of eddy modern-day dynamometer. The liquid gas glide rate is measured at the

volumetric foundation the use of a burette and a stopwatch. Provision is likewise made for interfacing airflow, temperatures and cargo measurement. The airflow is measured the use of an orifice meter and the exhaust gas temperatures are recorded with chromel- alumel thermocouples. The installation has stand-on my own panel container including air field, gas tank, manometer, gasoline measuring unit, transmitters for air and gasoline waft measurements, procedure indicator and engine indicator. Rota meters are provided for cooling water and calorimeter water waft measurement. A computerized Diesel injection strain dimension can be carried out thru sensor transmitters. The various additives of experimental set up are defined under. Fig.3.1 shows line diagram & Fig.Three.2 indicates the image of the experimental set up. The Instruments of the Experimental Setup are

- The engine
- Dynamometer
- Exhaust Gas Analyzer

III.1 The Engine:

The Engine selected to carry out experimentation is a unmarried cylinder, 4 stroke, vertical, water cooled, direct injection automated Kirloskar make CI Engine. This engine can withstand better pressures encountered and is also used considerably in agriculture and commercial sectors. Therefore this

Engine is selected for sporting experiments. Fig.3.Three shows the real snap shots of the C.I. Engine and its attachments.

III.2Dynamometer:

The engine has a DC electrical dynamometer to degree its output. The dynamometer is calibrated statistically earlier than use. The dynamometer is reversible i.E., it really works as monitoring as well as an soaking up tool. Load is controlled via changing the field modern-day. Eddy-Current Dynamometer's principle is primarily based on Eddy-Current (Fleming's right hand law). The production of eddy-present day dynamometer has a notched disc (rotor) which is driven with the aid of a prime mover (including engine, and many others.) and magnetic poles (stators) are placed out of doors with an opening. The coil which excites the magnetic pole is wound in circumferential course. When modern-day runs thru interesting coil, a magnetic flux loop is formed around the thrilling coil thru stators and a rotor. The rotation of rotor produces density difference, then eddy-contemporary goes to stator. The electromagnetic force is implemented contrary to the rotational direction via the product of this eddy-present day.

III.3 Exhaust Gas Analyzer

All emissions like Carbon monoxide, Carbon dioxide, Un-Burnt Hydrocarbons, Nitrogen oxide and unused oxygen are located in 5 fuel emission analyzer of version “MULTI GAS ANALYZER MN-05” is used. In this cable one end is hooked up to the inlet of the analyzer and the alternative quit is attached at the cease of the exhaust gas outlet. Continuous charging of the analyzer is essential to work in an powerful manner.Fig.Three.4 show the real snap shots of Exhaust Gas Analyzer. The measuring technique is primarily based on the precept of light absorption in the infrared location, called "non-dispersive infrared absorption". The broadband infrared radiation produced through the mild source passes via a chamber filled with gasoline, commonly methane or carbon dioxide. This gasoline absorbs radiation of a recognized wavelength and this absorption is a measure of the concentration of the gas. There is a narrow bandwidth optical filter at the end of the chamber to remove all other wavelengths before it is measured with a pyro-electric detector.

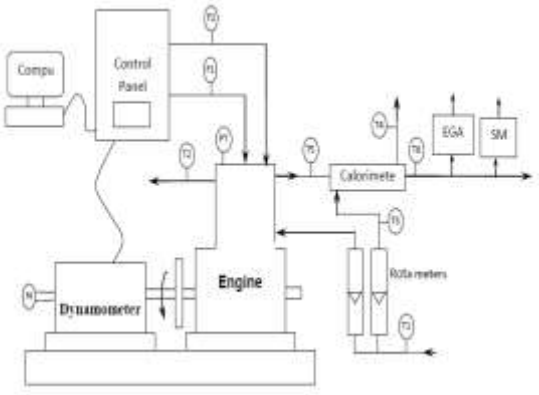

Fig III.1.Line diagram of Experimental set up

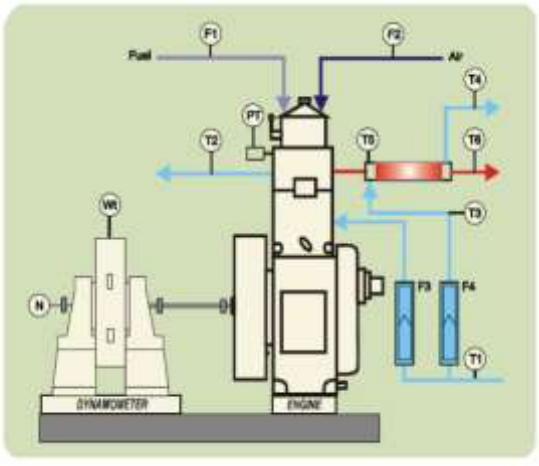

Fig III.2.Experimental setup with Instrumentation

Fig.III.3. Experimental setup of computerized CI Engine

Fig.III. 4. Five Gas Emission Analyzer Engine specifications

Table III. Engine specifications

Number of cylinders	01
Number of Strokes	04
Fuel	Diesel
Rated Power & Speed	5.2 KW/7 hp @ 1500 RPM
Cylinder bore & Stroke	87.5 & 110 mm
Compression Ratio	17.5:1
Dynamometer arm length	185 mm
Dynamometer Type	Eddy current
Type of cooling	Water cooled

IV. EXPERIMENTAL PROCEDURE

- To study the performance of 1 cylinder, 4 stroke, diesel engine ensure sufficient cooling water circulation for eddy current dynamometer and piezo sensor, engine and calorimeter.
- Start the set up and run the engine at no load condition for 4 to 5 minutes.
- Switch on the computer and run "Engine soft". Confirm engine soft configuration data is given below.
- Gradually increase load on the engine.
- Wait for steady state for 3 minutes and log the data in the "Engine soft".
- Gradually decrease the load.
- View the results and performance plots in "Engine soft".

V. INVESTIGATION INTO PERFORMANCE, EMISSIONS AND COMBUSTION CHARACTERISTICS

The experiments are conducted for variable loads like 0, 2, 4…up to 16 kg at engine speed of 1500 rpm for Hemispherical type piston and Flat type piston with injection pressures of 180,200,220,240 bar using fuels as Palm Stearin Methyl Ester (PSME), Animal Tallow Methyl Ester (ATME) and also on diesel with normal pressure on 4 stroke, single cylinder, water cooled, diesel engine connected to eddy current dynamometer in computerized mode in order to study the performance of engine. The performance parameters such as Brake Thermal Efficiency (ηB.Th.), Brake Specific Fuel Consumption (bsfc) and Exhaust Gas Temperature (EGT).Emission parameters such as Carbon Monoxide (CO), Carbon Dioxide (CO2), Un-burnt Hydro carbon (UHC), Nitrogen Oxides (NOx) and oxygen (O2) and also combustion characteristics are evaluated in this project. These performance and emission parameters of oils are compared to those of pure diesel. In this work two pistons are used with different geometry using biodiesel and diesel as fuel.

V.1 Results and Discussions on Engine Performance

Graphs at Injection Pressure of 180, 200, 220, 240 bar

Piston1-Hemispherical

Piston2-Flat

PSME- Palm Stearin Methyl Ester

ATME-Animal Tallow Methyl Ester

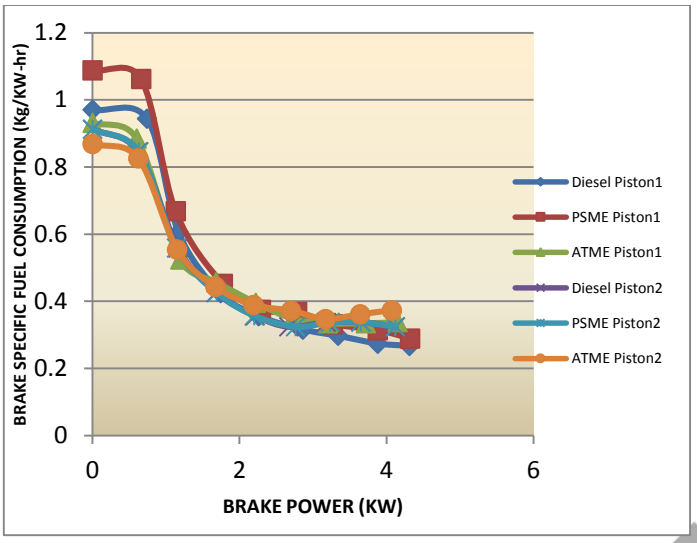

Fig V..1 Comparison Graph for BP vs BSFC at Injection pressure of 180 bar

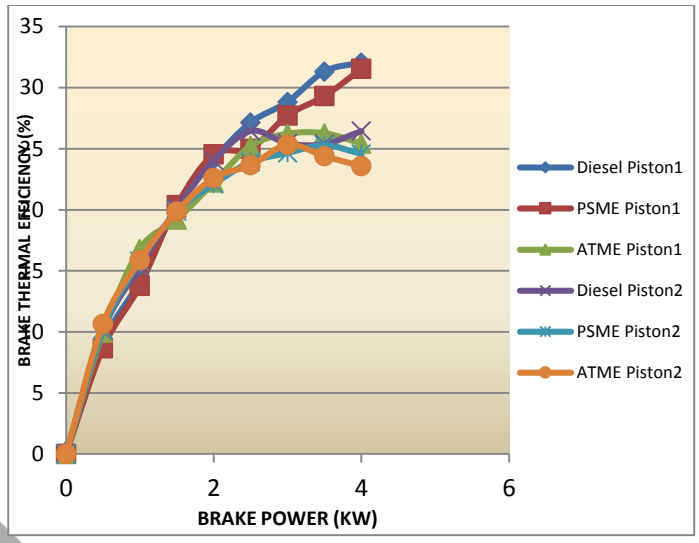

Fig V.2 Comparison Graph for BP vs BTHE at Injection Pressure of 180 bar

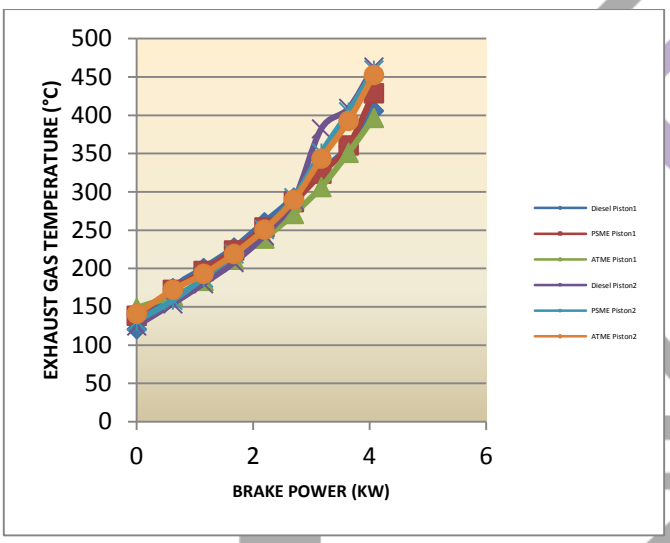

Fig 4.3 Comparison Graph for BP vs EGT at Injection Pressure of 180 Bar

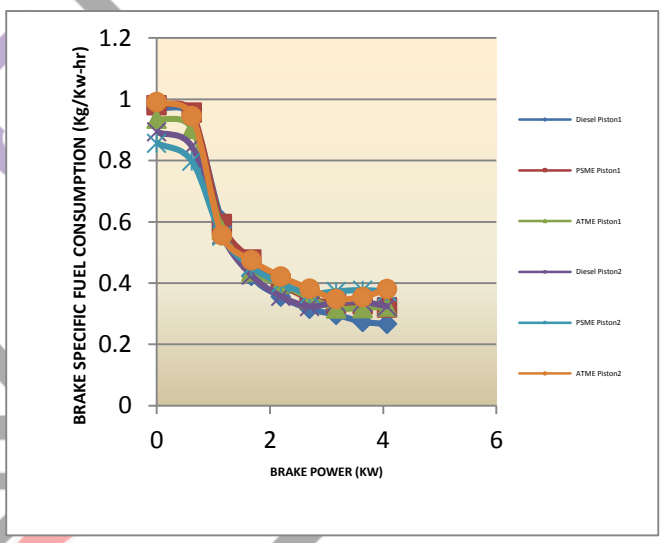

Fig 4.4 Comparison Graph for BP vs BSFC at Injection pressure of 200 bar

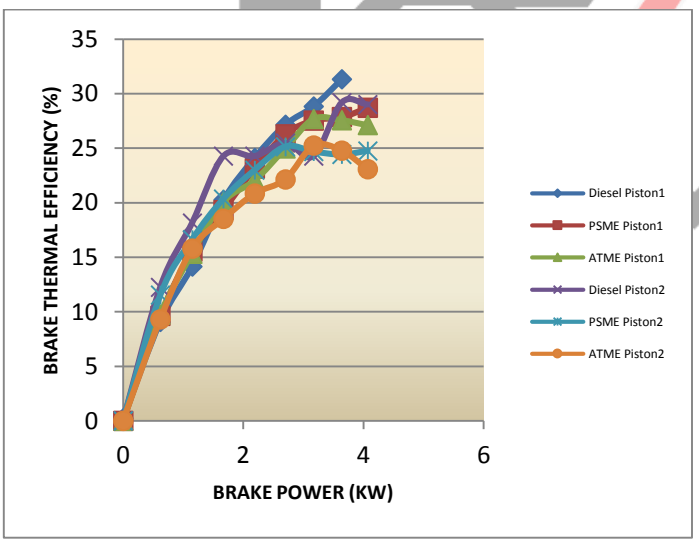

Fig 4.5 Comparison Graph for BP vs BTHE at Injection Pressure of 200 bar

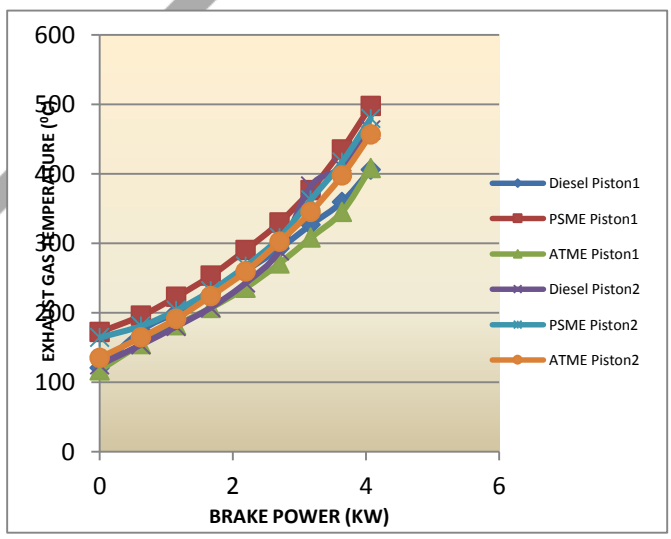

Fig 4.6 Comparison Graph for BP vs EGT at Injection Pressure of 200 bar

The Experimental Discussions from the above graphs for Engine Performance at different injection pressures of 180, 200, 220, 240 bars for Palm Stearin Methyl Ester (PSME), Animal Tallow Methyl Ester (ATME) and Diesel for both Hemispherical (Piston1) and Flat (Piston2) pistons are given below.

4.1.1 brake Specific Fuel Consumption:

Figures 4.1, 4.4, 4.7, 4.10 show comparison of Brake power with Brake Specific Fuel Consumption in case of Diesel with PSME and ATME for hemi spherical and flat piston at injection pressures of 180, 200, 220, 240 bars. From the graph it has been found that bsfc is decreasing for all pressures. For ATME Piston1 at a pressure of 240 bar the bsfc has lower value of 0.245 kg/kw-hr. At a pressure of 240 bar we have observed that the bsfc value for PSME Piston2 is slightly higher which is 0.4 kg/kw-hr comparing with diesel which is 0.267 kg/kw-hr. At rated load, bsfc for PSME Piston2 at a pressure of 240 bar is higher by 49.81% compared to Diesel. This observed phenomenon is due to higher viscosity of the fuel.

4.1.2 Brake Thermal Efficiency:

Figures 4.2, 4.5, 4.8, 4.11 show comparison of Brake power with Brake Thermal Efficiency in case of Diesel with PSME and ATME for hemi spherical and flat pistons at injection pressures of 180, 200, 220, 240 bars. From the graph it has been found that Brake Thermal Efficiency is increasing for all pressures. For PSME Piston2 at a pressure of 240 bar the Brake Thermal Efficiency has lower value of 23%. At a pressure of 240 bar we have observed that the Brake Thermal Efficiency value for ATME Piston1 is slightly higher which is 35.67% comparing with diesel which is 32.05%.This is attributed to lower calorific value, lower viscosity coupled with density of the fuel.

4.1.3 Exhaust Gas Temperature:

Figures 4.3, 4.6, 4.9, 4.12 show comparison of Brake power with Exhaust Gas Temperature in case of Diesel with PSME and ATME for both hemispherical and flat pistons at injection pressures of 180, 200, 220, 240 bars. From the graph it has been found that Exhaust Gas Temperature is increasing for all pressures. Exhaust Gas Temperature for ATME Piston1 at a pressure of 240 bar has lower value. However Exhaust Gas Temperature for PSME Piston1at a pressure of 200 bar has higher value compared to diesel. So ATME Piston1at 240 bar pressure has higher performance compared to other fuels due to reduction in exhaust heat loss.

4.2 Results and Discussions on Engine EMISSIONS

Graphs at Injection Pressure of 180, 200, 220, 240 bar

Piston1-Hemispherical

Piston2-Flat

PSME- Palm Stearin Methyl Ester

ATME-Animal Tallow Methyl Ester

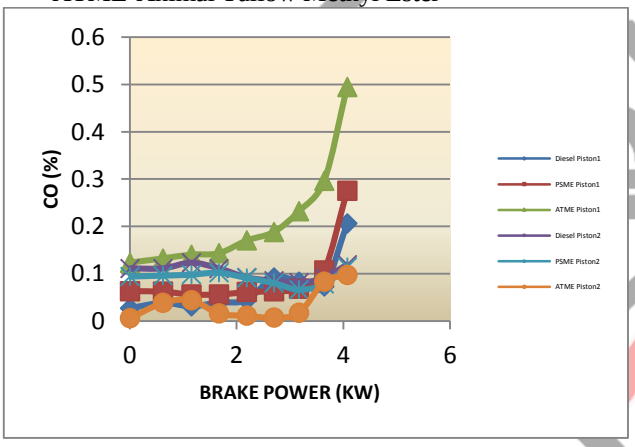

Fig 4.13 Comparison Graph for BP vs CO at Injection Pressure of 180 bar

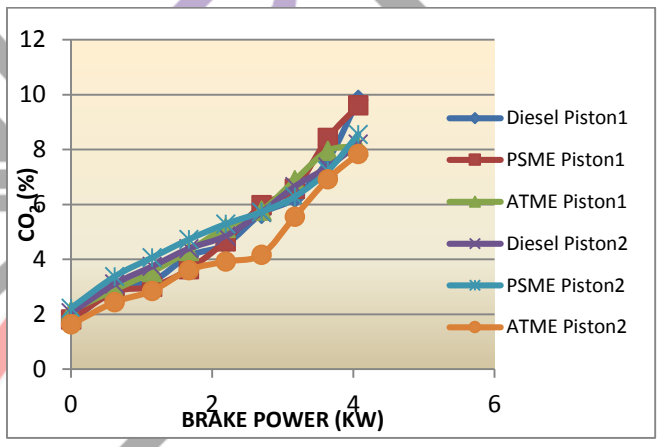

Fig 4.14 Comparison Graph for BP vs CO2 at Injection Pressure of 180 bar

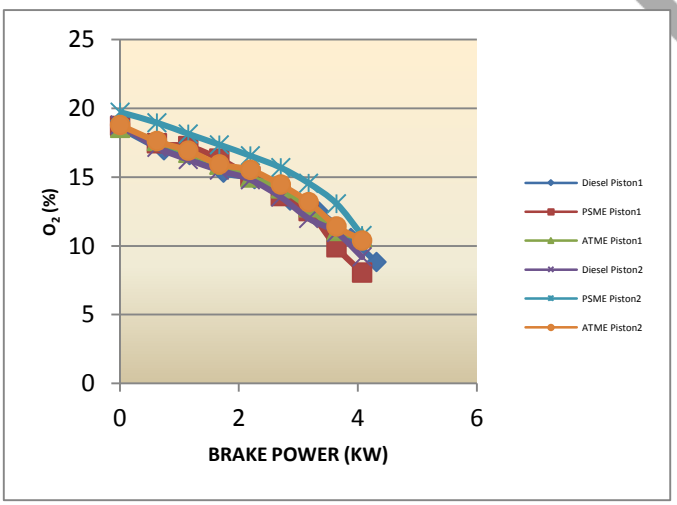

Fig 4.15 Comparison Graph for BP vs O2 at Injection Pressure of 180 bar

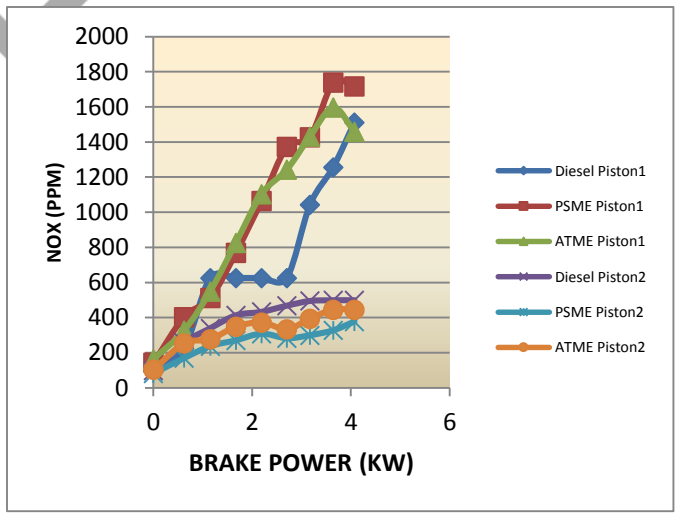

Fig 4.16 Comparison Graph for BP vs NOX at Injection Pressure of 180 bar

VI. Results and Discussions on Combustion Characteristics:

Graphs at Injection Pressure of 180, 200, 220, 240 bar

Piston1-Hemispherical

Piston2-Flat

PSME- Palm Stearin Methyl Ester

ATME-Animal Tallow Methyl Ester

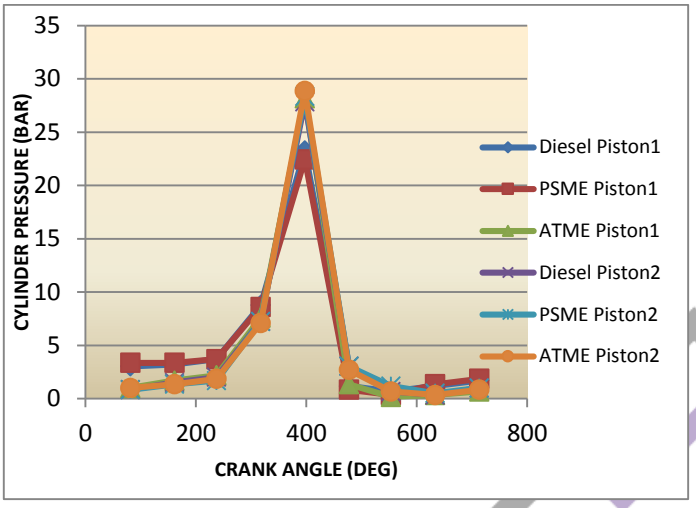

Fig 4.33 Comparison Graph for CA vs CYLINDER PRESSURE at Injection Pressure of 180bar

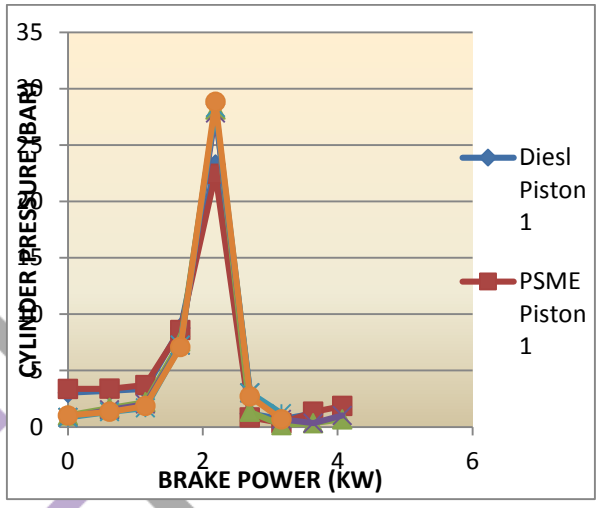

Fig 4.34 Comparison Graph for BP vs CYLINDER PRESSURE at Injection Pressure of 180bar

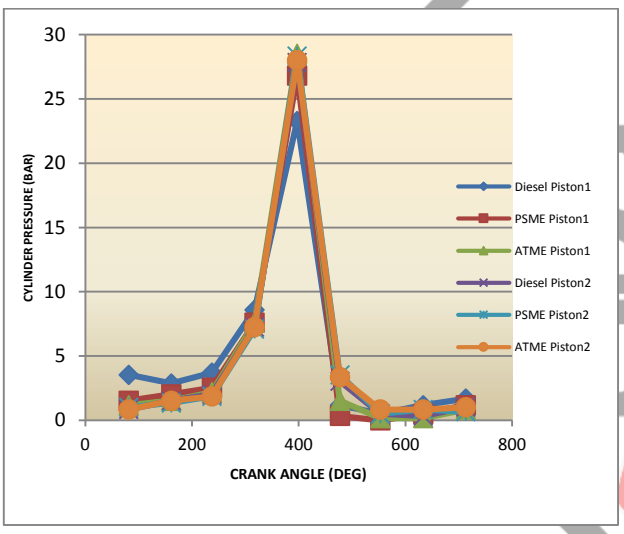

Fig 4.35 Comparison Graph for CA vs CYLINDER PRESSURE at Injection Pressure of 200bar

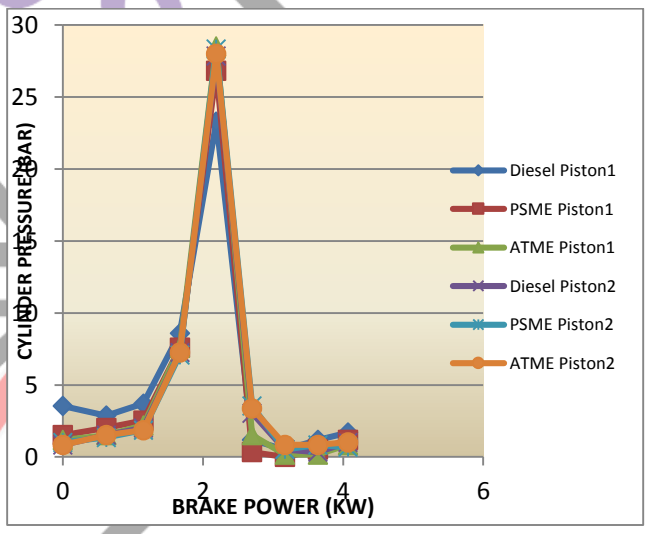

Fig 4.36 Comparison Graph for BP vs CYLINDER PRESSURE at Injection Pressure of 200bar

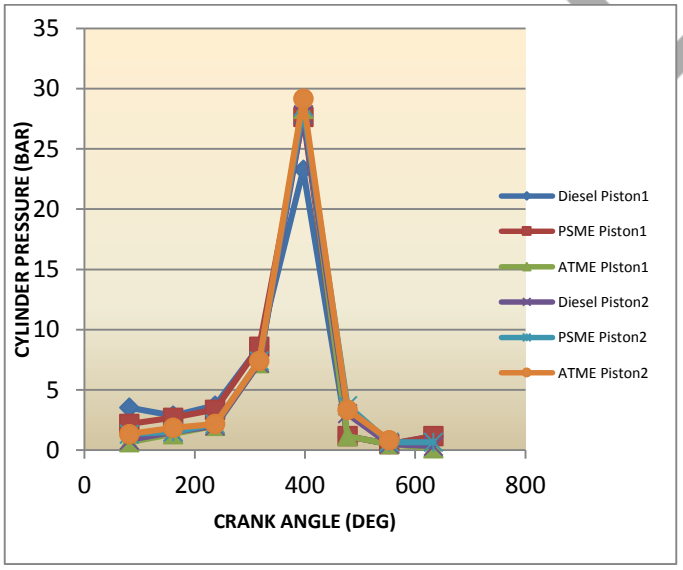

Fig 4.37 Comparison Graph for CA vs CYLINDER PRESSURE at Injection Pressure of 220bar

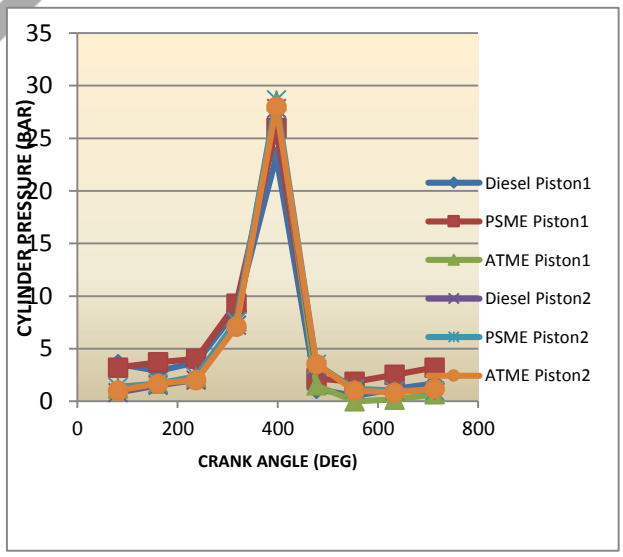

Fig 4.39 Comparison Graph for CA vs CYLINDER PRESSURE at Injection Pressure of 240bar

The Experimental Discussions from the above graphs for Combustion Characteristics at different injection pressures of 180, 200, 220, 240 bars for Palm Stearin Methyl Ester (PSME), Animal Tallow Methyl Ester (ATME) and Diesel for both Hemispherical (Piston1) and Flat (Piston2) pistons are given below.

- **Effect of Injection Pressure on Combustion Characteristics:**

Figures 4.33, 4.35, 4.37, 4.39 show comparison of Crank Angle with Cylinder Pressure in case of Diesel with PSME and ATME for both hemispherical and flat pistons at injection pressures of 180, 200, 220, 240 bars. The maximum rise of cylinder pressure during combustion near to TDC i.e. 325º-450º crank angle. ATME Piston1 at 220 bar is having higher in-cylinder pressure compared to all other fuels at different pressures. The result shows that peak cylinder pressure of engine running with biodiesel is slightly higher than engine running with diesel. The main cause for higher peak in-cylinder pressure in the CI engine running with biodiesel is because of the advanced combustion process initiated by easy flow-ability of bio-diesel due to the physical properties of biodiesel. In addition, owing to the presence of oxygen molecule in biodiesel, the hydrocarbons achieve complete combustion resulting in higher in-cylinder pressure.

- **Variation of Cylinder Pressure with Brake Power:**

Figures 4.34, 4.36, 4.38, 4.40 show comparison of Brake Power with Cylinder Pressure in case of Diesel with PSME and ATME for both hemispherical and flat pistons at injection pressures of 180, 200, 220, 240 bars. Figure shows the maximum rise of cylinder pressure is at 2.26 kw for brake power. The peak pressure of ATME Piston2 at 220 bar is slightly greater than Diesel and PSME for piston1 and piston2 at different pressures and peak pressures is decreased with preheating.

VII. CONCLUSIONS

In this work the experiments are conducted at varied injection pressures using two types of piston geometry. These experiments are conducted using Diesel, Blend of Palm Stearin Methyl Ester and Animal Tallow Methyl Ester to evaluate engine performance, emissions and combustion characteristics of CI diesel engine.

The conclusions drawn from this work are as follows:

- Kinematic Viscosity of the fuel is major influencing parameter in performance analysis of CI engines as it effects the atomization of fuel and thereby its performance. It was observed that Viscosity of B20 of Palm Stearin is very close to that of Diesel and viscosity values tend to deviate as the biodiesel percentage increase which means that B20 of Palm Stearin is best fuel that can be used in CI engine.
- The Brake Specific Fuel Consumption for Palm Stearin Methyl Ester (PSME) for Hemispherical and Flat bowl Pistons at Injection pressures of 180, 200, 220, 240 bar is higher than that of diesel. The PSME for Flat bowl piston at injection pressure of 240 bar is 49.81% higher than that of normal diesel; this is due to higher viscosity.
- The Brake Thermal Efficiency for Animal Tallow Methyl Ester (ATME) for hemispherical bowl piston at injection pressure of 240 bar is higher than that of normal diesel. This is because of lower calorific value of fuel, lower viscosity coupled with density of fuel.
- The CO emissions for Animal Tallow Methyl Ester (ATME) for Flat bowl piston at Injection pressure of 240 bar at a rated load is higher by 85.99% compared to diesel. This is as a result of incomplete combustion of fuel.
- The CO2 emissions for Palm Stearin Methyl Ester (PSME) for Flat bowl piston at injection pressure of 240 bar at a rated load is higher by 5.95% compared to diesel. The oxygen % is more in the combustion chamber for biodiesel compared to diesel, so there will be better combustion in the combustion chamber.
- The NOX emissions for Palm Stearin Methyl Ester (PSME) for Hemispherical bowl Piston for 200 bar at a rated load is higher by 11.59% compared to diesel. This is owing to higher peak combustion temperature in the combustion chamber influences this factor.
- The HC emissions for Palm Stearin Methyl Ester (PSME) for hemispherical bowl Piston at 180 bar is lower by 7.67% compared to diesel.
- The in-cylinder pressure for Animal Tallow Methyl Ester (ATME) for Hemispherical bowl piston at injection pressure of 220 bar is having higher in cylinder pressure compared to diesel near to TDC i.e., 325º-450º crank angle. The main cause for higher peak in cylinder pressure in the CI engine running with biodiesel is attributable to the advanced combustion process initiated by easy flow-ability of bio-diesel due to the physical properties of biodiesel.

From the above results, it has been found that performance, Emissions of Palm Stearin Methyl Ester (PSME) and Animal Tallow Methyl Ester (ATME) for both Hemispherical and Flat piston at injection pressure of 240 bar is superior when compared with normal standard diesel. The HC and NOX emissions for PSME and ATME at injection pressure of 180 and 220 bar are superior when compared with diesel. The in-cylinder pressure for ATME for Hemispherical piston at injection pressure of 220 bar is higher compared to diesel.

The experimental results also prove that Palm Stearin Methyl Ester (PSME) and Animal Tallow Methyl Ester (ATME) at injection pressure of 240 bar are best alternative fuels for diesel engine.

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