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EXPERIMENTAL INVESTIGATION OF CI ENGINE PERFORMANCE CHARACTERISTICS FUELLED BY SUSTAINABLE BIOFUEL

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ABSTRACT :

The use of diesel-ethanol mixtures in an engine that runs on diesel fuel was the subject of an experimental study. Initially, n-butanol was added to both the diesel and ethanol solutions to determine their solubility. In addition, we evaluated engines powered by diesel and those powered by the blends in order to learn more about their respective emissions and performance. The results of the tests demonstrate that n-butanol blends can successfully replace diesel in diesel engines. The thermal efficiencies of the engines powered by the blends were similar to diesel engines, although fuel consumption did increase somewhat due to ethanol's lower heating value. Additionally, the emissions' features were examined. When the engine was powered by the blends, the following results were observed: lower smoke emissions compared to diesel; lower carbon monoxide (CO) emissions at high speeds and loads; higher hydrocarbon (HC) emissions at low speeds and loads; and different nitrogen oxides (NOx) emissions at different speeds, loads, and blends.

Keywords: nitrogen oxides, carbon monoxide, fuel, diesel

Introduction :

Biodiesel is an alternative fuel that burns cleanly and is derived entirely from plant and animal sources. A lot of people think biodiesel will be the fuel of choice in the future. It is also called biofuel on occasion. In the last 10 years, biodiesel—a renewable, biodegradable, environmentally benign, and non-toxic fuel—has garnered a lot of interest. It is produced by esterifying fatty acids and transesterifying triglycerides. Environmental concerns and the depletion of essential resources like coal and petroleum have led to the substitution of biodiesel for diesel fuel derived from petroleum.

Research into and use of alternative fuels have been bolstered by the precipitous increase in the price of petroleum on global markets. Past investigations into various renewable fuels, including methanol, ethanol, biodiesel, waste cooking oil, and raw vegetable oil. Although the latter two are more commonly used with petrol engines, the first three are applicable to diesel ones as well. The versatility of the raw materials used to make ethanol—corn, maize, sugar beets, sugar cane, cassava, etc.—justifies its classification as a renewable fuel. However, ethanol has not yet been used commercially to partially replace diesel fuel in diesel engines. Due to its unique characteristics, ethanol has not yet been able to overcome the obstacles that have prevented its possible use as a fuel for diesel engines, although some research into this possibility has been conducted. The density and viscosity of ethanol are lower than those of diesel. Diesel is not a good candidate for mixing with ethanol because of its characteristics. Consequently, in order to make ethanol mixable with diesel and subsequently use it in diesel engines, additional research is required.

This study aims to conduct an experimental investigation into the diesel-ethanol solubility, diesel-ethanol blends with the additive n-butanol, and diesel engine performance and emissions when powered by these blends compared to pure diesel.

He and colleagues studied the efficiency of diesel engines that used a 10%/30% ethanol/diesel combination. At five distinct load circumstances, the emissions were recorded. Adding a small amount of CO to the exhaust greatly decreased smoke at high load. To a lesser extent, emissions of NOx and CO2 were also decreased. However, ethanol blended fuel had no impact on smoke emissions under low load conditions.

Using a Kirloskar HA394 diesel engine, Godiganur et al. studied the effects of fish oil methyl ester on performance and emissions. According to the findings, compared to diesel fuel, brake specific fuel consumption is greater for B100 fuel, but lower for B20 fuel. As the blend fraction increased, we saw a linear decrease in CO and HC emissions, but an increase in NOx for B100 gasoline.

Diesel engines run on bioethanol, diesel-biodiesel-ethanol, or a combination of the two were studied by Shahir et al. in terms of performance and emissions. The power output might be reduced by 4.4%-8.7% owing to a drop in the cetane number when diesel, biodiesel, and ethanol are used as fuel. Due to blended fuel's poor heating value, brake specific fuel consumption has increased. Brake thermal efficiency was higher with the combined fuel.A six-cylinder turbocharged diesel engine that ran on a mixture of ethanol and diesel was studied by Rakopoulos et al. on its performance and emission characteristics. The volume percentage of ethanol utilised ranged from 5% to 10%. Engine speeds and loads were varied during the test. Brake specific fuel consumption has been found to be higher. Although emissions of carbon monoxide and nitrous oxide did not significantly decrease. Compared to utilising pure diesel fuel, ethanol-blended fuel increases the emission of unburned hydrocarbons.

The performance parameters and engine emissions of a diesel engine that used maize oil methyl ester with oxygenated additives were studied experimentally by Manigandan et al. Pentanol and titanium oxide were the additives utilised to enhance the diesel engine's performance and decrease emissions. To conduct the experiment, various combinations of corn vegetable methyl ester were utilised. Results were best when using a combination of 20% pentanol and 5% titanium oxide in corn oil methyl ester, according to the study. Brake specific fuel consumption was discovered to have dropped by 6.3%. The amount of smoke, hydrocarbons, and carbon monoxide (CO) released into the air is reduced. Not only that, but NOx and PM emissions were found to be decreased by 16%.

In order to determine how well a diesel engine ran on biodiesel, ethanol, and n-butanol blends, Wei et al. conducted research. A mixture of 95% biodiesel and 5% ethanol was designated as BE5, followed by BE10, BE15, and BBu (consisting of 95% biodiesel and 5% n-butanol), BBu10, and BBu15. We tested the engine's performance and emissions under five distinct loads. According to the research, engine performance is negatively affected by BE mixes in comparison to BBu blend. On top of that, employing BBu resulted in a 13.7% rise in CO emissions, while utilising BE resulted in a 22.8% increase. Using BBu and BE, respectively, has reduced NOx emissions by 6.5% and 28%, PM by 20.7% and 20.6%, and particle concentration from emissions by 22% and 21%.A study conducted by Patra et al. (2021) examined the gradual pyrolysis of agro-food byproducts, specifically canola and oat hulls. The main objective of this study was to uncover the characteristics of food scraps and agricultural crop byproducts (such as canola and oar hulls). Aromatic and phenolic groups were found in the pyrolysis oil that was created at higher temperatures, according to the investigators. Lower temperatures (300°C), shorter reaction times (30 minutes), and heating rates (5°C/min) were found to provide the highest bio-char yields (52 wt%) from food waste. Further evidence of increased H_2 and CH_4 yields was provided by the gaseous product obtained at 600° C.

Lagerstroemia speciosa seed hull feedstock was the subject of a pyrolysis performance analysis, kinetic study, and physicochemical examination by Nawaz et al. (2021). Lagerstroemia speciosa seed biomass showed limitless bioenergy feedstock in terms of chemical and physical qualities, according to the scientists. Lagerstroemiaspeciosa seed biomass was subjected to a thermal stability research at dynamic heating rates. The results showed that increasing the heating rates caused the degradation band to move up without negatively impacting degradation performance.

An in-depth analysis of the successes and failures of food waste management by co-pyrolysis and pyrolysis was provided by Su et al. (2021). Traditional methods of disposing of food waste, such as landfilling, composting, anaerobic digestion, and feeding animals, have a hard time alleviating environmental problems due to their high levels of inefficiency, land occupation, and virus transmission, as this review demonstrates. In contrast, the pyrolysis technique offers a promising alternative. By converting food scraps into bioenergy, the pyrolysis process offers a potential solution to the environmental catastrophe.

Experimentally evaluating the performance characteristics of a Compression Ignition (CI) engine powered by sustainable biofuel is the main goal of this study. Using biofuel as a power source, this study will compare the engine's thermal efficiency, emissions profile, and combustion properties to those of conventional diesel. The goal of the research is to detect and analyse factors such as ignition delay, hydrocarbons, particulate matter, nitrogen oxides, carbon monoxide, and brake specific fuel consumption. To further understand the possible advantages and disadvantages of using sustainable ethanol, the study will also look for differences in power production, torque, and combustion stability.

METHODOLOGY AND MATERIALS :

The experimental research of the performance characteristics of Compression Ignition (CI) engines powered by sustainable biofuel follows a methodical technique. The first step of the research is to create synthetic gasoline using environmentally friendly ingredients, following all relevant procedures and meeting all experimental requirements. In order to set reference parameters, the experimental setup involves baseline testing using conventional diesel. After that, eco-friendly synthetic fuel is put to the test through a battery of tests with different loads and speeds to find out all about its combustion characteristics, emissions, and efficiency. Accurate data acquisition systems are used to gather information, which is then evaluated and contrasted with previously gathered data. Experimental results inform the exploration of optimisation opportunities, such as changes to the injection timing or compression ratio. This work contributes to our understanding of sustainable synthetic fuel utilisation in CI engines by applying statistical analysis to validate results and meticulously documenting the entire process for peer review and publication.

2.1 Experimental Procedure and Setup

It is essential to pay close attention to the experimental approach and setup while running tests with ethanol and diesel mixtures in a compression ignition (CI) engine. First, choose a suitable CI engine and check that it can run on the ethanol-diesel mixtures you want to use. Dynamometers and exhaust gas analyzers, among other performance and emissions analysis tools, should be installed in the engine.

To make the ethanol-diesel blend, the ingredients must be thoroughly mixed until they form a homogenous liquid. This may include emulsifiers. To ensure consistency and avoid contamination, this blending process should be carried out in a controlled environment. After the mixture is ready, it is tested by adding it to the engine system. Exhaust emissions, combustion characteristics, fuel consumption rates, engine power output, and other metrics are tracked and recorded during the testing process. Since ethanol mixes might influence the starting behaviour of CI engines, cold start performance may receive further consideration. Tests to determine the effects on engine parts and their longevity can potentially be a part of the experimental setup. To determine whether the ethanol-diesel mix has produced any wear or degradation, the engine may need to be run for long periods of time. Evaluating the compatibility, performance, and emissions of ethanol and diesel blends in CI engines requires a well-planned experimental approach and equipment.

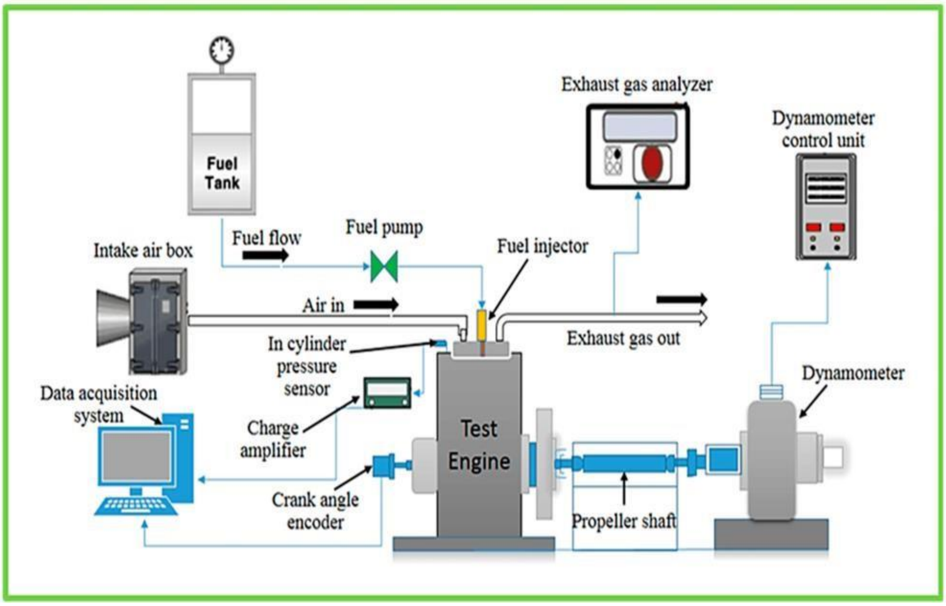


Fig 1 Schematic illustration of the experimental setup

2.2 MATERIALS

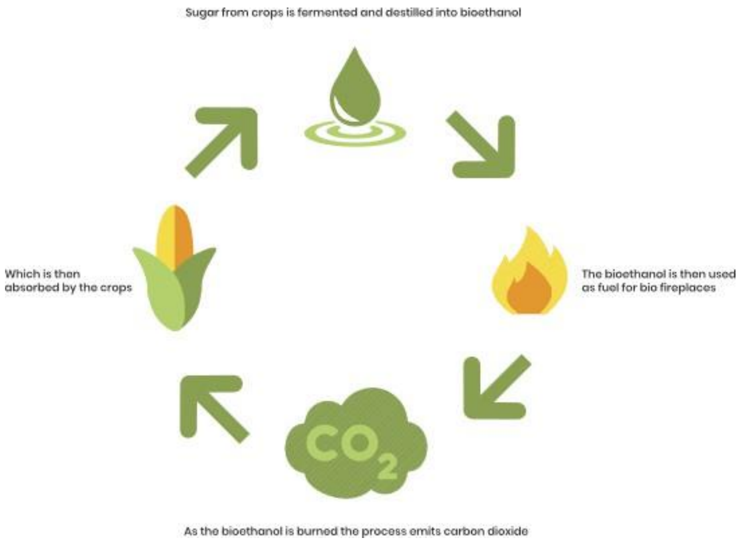
The materials used in an experimental investigation of Compression Ignition (CI) engine performance characteristics fueled by sustainable synthetic fuel are critical for ensuring accurate and reliable results. The key materials include:

- Ethanol
- CI Engine
- Instrumentation and Sensors
- Dynamometer
- Temperature sensor
- Testing Facility
- Analyzer for Emissions
- Lab Equipment for Fuel Analysis
- Safety Equipment
- Materials for Engine Modifications

Sustainable Biofuel

A carbon-neutral substitute for conventional fossil fuels, sustainable biofuel ethanol may increase energy independence while decreasing emissions of greenhouse gases. It is produced from renewable biomass sources, such as sugarcane or maize. As a potential, environmentally benign option in the worldwide shift towards cleaner energy systems, it does this through efficient production methods and the use of waste.

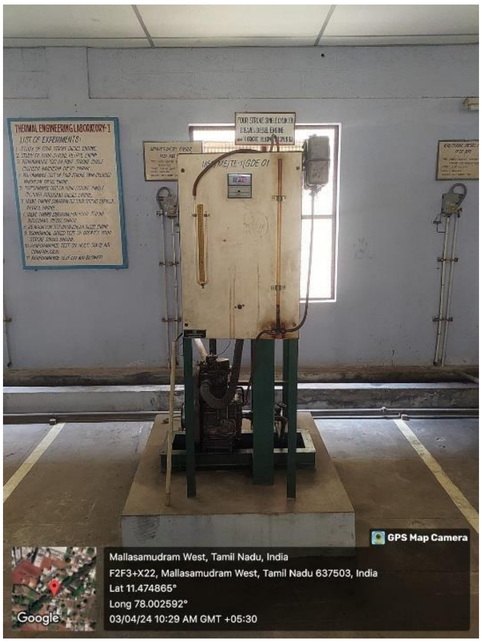
Fig 2 Sustainable Biofuel



2.2.2 CI Engine

It is critical to select a CI engine that can work with synthetic fuel injection. To get the most out of the synthetic fuel and get reliable results from performance parameter measurements, some tweaks might be in order.

Fig. 3 CI Engine



2.2.3 Instrumentation and Sensors

Accurate data gathering requires sensors of high quality. Here you can find sensors that measure things like engine speed, torque, temperature, pressure, and pollutants from the exhaust gas. To get accurate readings, these sensors must be regularly calibrated and serviced.

Fig. 4 Speed sensor

Temperature sensor

One way to detect the temperature of a given area is with a temperature sensor, which then turns that reading into an electrical output. Environmental monitoring and process control are only two examples of the many uses for these sensors in the industrial sector. Temperature sensors, thanks to their small form factor and cutting-edge technology, are able to give precise and trustworthy temperature readings, paving the way for safe and effective operations in several fields.

Fig. 4.2.4 Temperature sensor

Data Acquisition System

The collection and monitoring of engine performance information in real-time requires a high-tech data acquisition system. Experiment data generated at high frequencies should be manageable by this system.

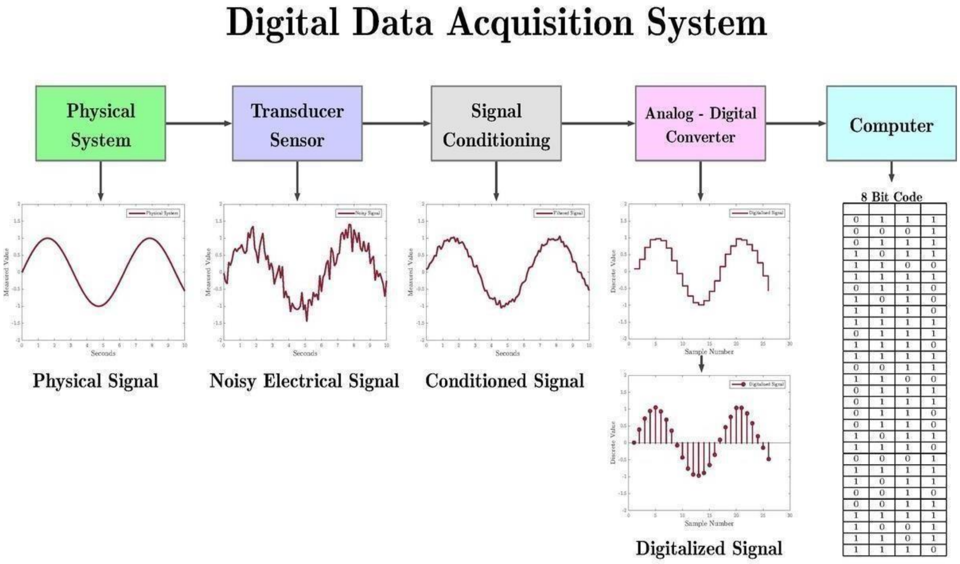


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Fig. 4.2.5 Data Acquisition System

Testing Facility

An appropriately designed testing facility with controlled environmental conditions is essential to ensure consistency in the experimental setup. This includes considerations for temperature, humidity, and pressure.

Analyzer for Emissions

Instruments for analyzing exhaust emissions, such as nitrogen oxides (NOx), carbon monoxide (CO), hydrocarbons (HC), and particulate matter, are crucial for assessing the environmental impact of the synthetic fuel.

Lab Equipment for Fuel Analysis

Laboratory equipment for analyzing the physical and chemical properties of the synthetic fuel, such as viscosity, density, and cetane number, is important for understanding its combustion characteristics and compatibility with the engine.

Safety Equipment

Safety measures, including fire extinguishers, emergency shutdown systems, and personal protective equipment, are critical to ensure the well-being of researchers and to address any unforeseen circumstances during experiments.

Materials for Engine Modifications

If modifications are made to the CI engine for compatibility with biofuel, appropriate materials for these modifications should be selected to ensure durability and safety.

EXPERIMENTAL PROCESS

Three different ratios of ethanol to diesel were prepared for our experiment: 5:95, 10:90, and 15:85. For each combination, we used graduated cylinders to measure the amounts of ethanol and diesel: 50 mL of ethanol with 950 mL of diesel, 100 mL of ethanol with 900 mL of diesel, and 150 mL of ethanol with 850 mL of diesel. After we made sure everything was clean and that everyone was wearing protective gear, we mixed the ratios thoroughly in sealed containers. We made sure to preserve the combinations in airtight containers with labels, following all local rules for safe handling and disposal. The purpose of the optional engine testing was to measure performance parameters such as emissions and fuel consumption.

2.3.1 Equipment and Materials

We used the following equipment and materials:

- ✓ Ethanol
- ✓ Diesel fuel
- ✓ Graduated cylinders or volumetric flasks for precise measurements
- ✓ Mixing containers with airtight seals
- ✓ Stirring rod or mechanical stirrer
- ✓ Safety equipment: gloves, goggles, lab coat, and a fume hood
- ✓ Hydrometer
- ✓ Thermometer
- ✓ Additives
- ✓ Engine testing setup

2.3.2 Preparation

- ✓ We made sure all the equipment was clean and dry.
- ✓ We set up our mixing area in a well-ventilated space or under a fume hood.
- ✓ We wore appropriate safety gear.
- ✓ Measuring and Mixing

2.3.3 Diesel only

To get a feel for the CI engine's capabilities, we started by feeding it diesel alone. In order to compare the ethanol-diesel mixes' performance to this benchmark, this step was critical. Among the many metrics we documented were the engine's temperature, fuel level, speed, power, and emissions. To evaluate the effects of blending ethanol with diesel fuel, we needed a thorough set of data, and these baseline results provide just that. To guarantee precision and dependability, the measurements were conducted in a controlled environment.

Calculate volumes:
For a total volume of 1000 mL (1 liter):

Ethanol:
1000 mL×0.05=50 mL
1000 mL×0.05=50 mL

Diesel:
1000 mL×0.95=950 mL
1000 mL×0.95=950 mL

Measure ethanol:
We used a graduated cylinder to measure 50 mL of ethanol.

Measure diesel:
We measured 950 mL of diesel in another graduated cylinder.

Mix:
We poured the ethanol into the mixing container followed by the diesel. We stirred thoroughly using a stirring rod.

Seal:
We closed the container with an airtight seal.

RESULTS :

S. No	Speed	Load	Time taken 10cc fuel Consumption (min)	Engine Temperature (C)	Inlet valve Temperature (C)	Exhaust valve Temperature (C)
1	2540	0	1.34	39.9	37.1	30.5
2	2490	2	1.27	43.3	38.9	31.7
3	2450	3	1.30	45.4	39.9	31.8
4	2430	5	1.10	46.4	40.1	32.2

ADVANTAGES AND APPLICATIONS

2.5.1 Advantages

- ✓ Environmental Sustainability
- ✓ Reduced Dependency on Fossil Fuels
- ✓ Tailored Fuel Properties
- ✓ Compatibility with Existing Infrastructure
- ✓ Fuel Flexibility
- ✓ Enhanced Combustion Characteristics
- ✓ Reduced Emissions
- ✓ Optimization Opportunities
- ✓ Contribution to Sustainable Transportation

2.5.2 Applications

- ✓ Combustion efficiency and emissions are affected by the core material, which is sustainable biofuel sourced from renewable resources.
- ✓ The performance outcomes are determined by the CI engine, which may need to be modified for compatibility reasons.
- ✓ The engine's reaction to synthetic fuel can be better understood with the help of precise data acquired by high-quality sensors and instrumentation materials.

3. CONCLUSION :

With the use of pure diesel in a CI engine, the experiment was able to establish baseline performance measures, which are crucial for comparison. We tested the effects on engine performance and behaviour by mixing ethanol and diesel at three different ratios (5:95, 10:90, and 15:85). Engine temperature, fuel consumption, speed, power output, and pollutants were some of the metrics that changed noticeably when diesel with ethanol added to it. While it is possible to mix ethanol with diesel, these results show that doing so alters the engine's performance. This study's extensive findings will help optimise ethanol-diesel blends for CI engines, leading to greater efficiency and reduced emissions.

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