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EXPERIMENTAL INVESTIGATION ON PERFORMANCE AND EMISSION CHARACTERISTICS OF DIESEL ENGINE WITH WASTE COOKING OIL BIODIESEL

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ABSTRACT:
This experimental study investigates the performance and emission characteristics of a diesel engine fuelled with waste cooking oil biodiesel. The investigation involved testing a diesel engine using waste cooking oil biodiesel. Engine performance parameters such as brake power, brake-specific fuel consumption, brake thermal efficiency and emissions oxides of nitrogen (NO_X), Carbon Monoxide (CO), Hydro carbon (HC), Carbon Dioxide (Co_2). were measured and compared with conventional diesel fuel. And find the significant results of reductions of emissions, and conclude the study. The study concludes that biodiesel is a viable alternative fuel for diesel engines, offering improved emission characteristics with minimal effects on engine performance.

Keywords:
Biodiesel, Diesel Engine, Performance, Emissions, Alternative Fuel.

1.Introdution:

Diesel engines were created in 1892 by Rudolf Diesel, who was granted a patent in 1893. His engine was initially designed to run on unrefined biodiesel. Vegetable oils were utilized as diesel. Fuel in the 1930s and 1940s, but only under dire circumstances biofuels are being introduced. A type of renewable energy known as biofuels is produced from organic resources like plants, crops, agate, and animal waste. Because they emit fewer greenhouse gas emissions when burned, these fuels are seen as more environmentally friendly substitutes for fossil fuels because they lessen air pollution and climate change. Biofuels are a type of renewable energy derived from organic materials or biomass. These fuels are considered an alternative to traditional fossil fuels and are produced from living organisms or their byproducts. The two main types of biofuels are bioethanol and biodiesel.

Bioethanol:
Source: Bioethanol is typically produced from sugars and starches found in crops such as corn, sugarcane, and wheat. It can also be derived from cellulosic biomass, including agricultural residues and wood. Production: The production process involves fermenting sugars or starches into ethanol using microorganisms like yeast. The resulting ethanol can be blended with gasoline for use in vehicles.
Biodiesel:
Source: Biodiesel is primarily made from vegetable oils, animal fats, and recycled cooking oil. Common feedstocks include soybean oil, canola oil, and palm oil. Production: Biodiesel is produced through a chemical process called transesterification, where the fats or oils are combined with alcohol (usually methanol or ethanol) and a catalyst. This reaction produces biodiesel and glycerol.
WASTE COOKING OIL BIO DIESEL:

Waste Cooking Oil Biodiesel is a renewable biofuel produced by converting used cooking oil (UCO) into a diesel substitute. The process typically involves a chemical reaction called transesterification, where the waste oil reacts with an alcohol (e.g., methanol or ethanol) in the presence of a catalyst to produce biodiesel and glycerin as a by-product as show in the fig 1.1.

Fig 1 waste cooking oil

2.LITERATURE REVIEW:

In this literature review, we explore various mechanisms for lifting side standards, drawing insights from relevant studies cited below:

Aisha F. Fareed et.al. [1] Waste cooking oil (WCO) and castor oil were used as biodiesel feedstocks via esterification and transesterification. Blends of 10% and 20% with diesel were tested for emissions, performance, and combustion at 3000 rpm. Specific fuel consumption increased by 2–8.5%, while thermal efficiency dropped by 2.5–9.5%. CO emissions decreased by up to 3.5%, HC by 14%, and smoke by 11%, but NOx rose by 6.5%. Peak cylinder pressure and heat release rate declined. Hybrid blends of 10% WCO and 10% castor biodiesel improved combustion and reduced emissions. Future studies should optimize biodiesel blends using modeling and thermodynamic assessments.

Tariq Mahmood et.al. [2] This study explores the production, economic feasibility, and engine performance of distilled waste cooking oil (WCO) biodiesel. WCO was converted into biodiesel through transesterification, yielding 87%, and further purified via vacuum distillation to achieve a 97% yield. The distilled biodiesel's properties, including density (871 kg/m^3) and viscosity (3.9 cSt), were closer to mineral diesel, allowing for better fuel blending. The calorific value improved to 42 MJ/kg, enhancing energy output. Engine tests with 10% and 20% distilled biodiesel blends showed improved performance and lower emissions. Economic analysis confirmed its feasibility as an alternative fuel without engine modifications.

M. Sonachalam et.al. [3] This study examines the effects of adding 30 ppm Multi-Walled Carbon Nanotubes (MWCNTs) to 5% and 10% ethanol-blended biodiesel (B20+E10) in a diesel engine. MWCNTs enhance combustion efficiency and lower emissions. The optimal blend (B20+E10+30 ppm MWCNT) increased Brake Thermal Efficiency (BTE) from 3.1% to 3.4% and reduced fuel consumption by 2.5%. Emissions of NOx, CO, and HC dropped by 35%, 37%, and 39%, respectively. Peak Heat Release Rate (HRR) improved, and ignition delay decreased, leading to better combustion. Statistical analysis showed that the XGBoost model outperformed others in predicting performance metrics.

M. Rakib Uddin et.al. [4] Biodiesel was synthesized from Waste Cooking Oil (WCO) using a three step method: saponification, acidification, and esterification. WCO, with 1.9 wt% Free Fatty Acid (FFA) and 47.6 mm^2/s viscosity, was sourced from Sylhet, Bangladesh. This method achieved higher biodiesel yields than conventional transesterification. The depletion of fossil fuels and environmental concerns have driven interest in alternative fuels. Vegetable oils, with calorific values similar to diesel, are promising substitutes. However, diesel engines emit pollutants harmful to health and the environment. WCO properties, including viscosity, specific gravity, and saponification value, were analysed. The optimized process efficiently converted FFAs into biodiesel, improving yield and sustainability. This study confirms the three-step method as a viable approach to biodiesel production.

A. Khalid et.al. [5] Biodiesel is produced by chemically reacting lipids from palm, vegetable, waste cooking oils, and animal fats with alcohol to form fatty acid esters. A key drawback is its inefficiency in cold weather. Viscosity affects fuel flow rate and atomization, impacting combustion. Diesel engines, widely used in construction, transportation, and agriculture, contribute significantly to air pollution. Biodiesel use in heavy vehicles is rising due to favourable fuel properties. Brake thermal efficiency improves with increasing compression ratios, reaching a maximum of 30.46% for B25 at CR 18, which is 5% higher than diesel. CO emissions from B25 are lower than standard diesel. Specific fuel consumption decreases with higher compression ratios; B25 at CR 18 records 0.28 kg/kWh versus 0.29 kg/kWh for diesel. Karanja oil blends exhibit higher combustion pressure at high compression ratios due to longer ignition delay and lower heat release rates compared to diesel.

S. Padmanabhan et. al. [6] Diesel is the primary global transportation fuel due to its efficiency, cost-efficiency, and environmental benefits. However, diesel engine emissions pose a significant environmental risk. This research explores biodiesel blends from aloe vera oil with cerium oxide additives, revealing that B30 (30% biodiesel, 68% diesel, and 1% cerium oxide) offers better performance and emission characteristics. Cerium oxide can improve cetane number value for better combustion. The study found that the best combination of blends and additives, B30 (30% biodiesel, 1% Nano additive, and 68% diesel), provides a promising alternative for environmentally friendly biodiesel.

Marcelo Silva et. al. [7] The increasing demand for clean energy and the impact of non- renewable fuels have led to a search for biodiesel derived from plants, with a priority given to aloe vera, a plant found in arid or tropical regions. The biodiesel is produced by extracting a colorless, viscous gel from the leaf of aloe vera, which adapts to the transesterification process. Although similar to regular diesel, biodiesel is biodegradable. The study aims to use aloe vera as a viable raw material for biodiesel production.

P. Vindhya et. al. [8] The increasing interest in alternative fuels for diesel engines has led to a global search for renewable, less pollutant, and agricultural-based alternatives. Aloevera, a crop with excellent properties, can be used in diesel engines to save heat lost in exhaust. An experimental study comparing aloevera and diesel blends with an EGR system was conducted on a single cylinder, four stroke, constant speed, water- cooled, electric-loaded, D.I. Diesel Engine. Results showed that aloevera had a 5% increase in BSFC, a 14% decreasein ηbth a 54.57% increase in ηvol, a 25% increase in CO_2, a 22.45 ppm HC, a 19.82O_2 and an 8.5% increase in NOx.

G. Kasiraman et. al. [9] The use of neat cashew nut shell oil (CSNO) in direct injection diesel engines has issues with incomplete combustion and low brake thermal efficiency due to its high viscosity. To address this, CSNO was blended with camphor oil (CMPRO), which is less viscous and burns readily. The blends were tested in a single cylinder 1500 rpm, 5.2 kW, direct injection diesel engine. The results showed that the 30% camphor oil blend with CSNO (CMPRO 30) showed good performance on par with diesel fuel operation in terms of brake thermal efficiency and heat release rate at full load. The CMPRO 30 blend also exhibited lower NOx emissions than the base diesel engine, with NOx emissions of 1040 ppm, 1068 ppm, and 983 ppm. The smoke emissions were higher for neat CSNO, but the CMPRO 30 blend and diesel fuel were comparable. The long-term usage of CSNO and CMPRO is needed to determine engine deposits.

Bhupendra Singh Chauhan et. al. [10] Diesel engines are essential in transport, agriculture, and power sectors, but their high viscosity has led to concerns about environmental norms and fossil fuels. The study aims to reduce the viscosity of Jatropha curcas oil by heating exhaust gases before feeding the engine. The results show that the brake thermal efficiency (BTE) of the engine is lower and the brake specific energy consumption (BSEC) is higher when fueled with Jatropha oil compared to diesel fuel. However, the engine performance is slightlyinferior with unheated Jatropha oil, but as fuel inlet temperature increases,viscosity decreases, and engine performance improves. Preheated Jatropha oil has superior performance and emissions, but NOx emissions increase with higher fuel inlet temperature. The optimal fuel inlet temperature is 80°C, considering BTE, BSEC, and gaseous emissions, durability, and safe engine operation.

K. Anand et. al. [11] The focus on alternative fuels research has increased due to rising crude oil prices, stringent emission norms, and environmental concerns. Biodiesel, a processed form of vegetable oil, has emerged as a potential substitute for diesel fuel due to its renewable source and lower emissions. An experimental study on a turbocharged, direct injection, multi-cylindertruck diesel engine using biodiesel-methanol blend and neat karanji oil derived biodiesel showed that the biodiesel-methanol blend had slightly higher ignition delay and maximum pressure rise compared to neat biodiesel. However, peak cylinder pressure and peak energy release rate decreased. The biodiesel-methanol blend also showed a significant reduction in nitric oxide and smoke emissions. The study suggests that the results are for a single constant speed operation of the engine, and some deviations may occur under different engine speeds

M. Mani et. al. [12] The search for alternative fuels for internal combustion engines has led to increased interest in waste plastics as a non-biodegradable and renewable fuel. Waste plastic oil has been found to be effective in compression ignition engines. Experimental research on a single cylinder, four stroke, direct injection diesel engine using waste plastic oil showed that retarded injection timing reduced oxides of nitrogen, carbon monoxide, and unburned hydrocarbon, while increasing brake thermal efficiency, carbon dioxide, and smoke. The study also found that the engine could run with 100% waste plastic oil, with marginally lower cylinder peak pressure and higher brake thermal efficiency.

M. Gumus et. al. [13] The study investigates the use of apricot seed kernel oil methyl ester as an alternative fuel for diesel engines. The oil was transesterified with methanol and potassium hydroxide as a catalyst, resulting in a methyl ester. The blends were tested in a compression ignition diesel engine, and the results showed that lower concentrations of the oil methyl ester improved engine performance and emissions. The ASKO, extracted from bitter apricot seed kernel, was also considered as a potential alternative fuel. The study suggests that using ASKOME as diesel fuel could improve the agriculture economy and reduce fuel availability decisions.

N.R. Banapurmath et. al. [14] The high viscosity of vegetable oils can cause issues in pumping and spray characteristics, and inefficient mixing with air can lead to incomplete combustion. To use vegetable oils as fuel in compression ignition (CI) engines, they can be converted into biodiesel, a methyl or ethyl ester of fatty acids made from vegetable oils and animal fat. Biodiesel can be used in its pure form or blended with diesel, and can be used in CI engines with minimal modifications. This paper investigates the performance of a single-cylinder, four- stroke, direct-injection CI engine operated with methyl esters of Honge oil, Jatropha oil, and sesame oil. Results show higher brake thermal efficiency and lower emissions compared to methyl esters of Honge and Jatropha oil

P.K. Sahoo et. al. [15] The study focuses on the use of non-edible oil-based methyl esters, such as jatropha, karanja, and polanga, blended with conventional diesel to create a substitute fuel for a water-cooled three-cylinder tractor engine. The results show that the transesterification process improves the fuel properties of the oil, including density, calorific value, viscosity, flash point, cloud point, and pour point. The methyl esters of these oils have similar fuel properties to diesel, making them suitable for existing engines without any hardware modifications. The addition of biodiesel to diesel fuel changes the physico- chemical properties of the blends, with the best brake-specific fuel consumption improvement observed with JB20. The biodiesel proportion of more than 20% in the blend decreases BSFC, and blends with higher biodiesel percentages decrease exhaust smoke substantially. However, there is a slight increase in carbon monoxide, oxides of nitrogen, and combine HC and NOx.

Sathiskumar.S et. al. [16] This study evaluates the performance and emission characteristics of a single cylinder 4-stroke multi-fuel VCR engine using aloe vera gel as a raw material for biodiesel production. The biodiesel reduced hydrocarbon and carbon monoxide emissions but emitted more nitrous oxide and increased fuel consumption. To address these drawbacks, aluminum oxide (Al2O3) was added as a nano additive. The best blend was chosen using design optimization software called "Design Expert". The results showed that B20 was the best blend, with aluminum oxide nano additives at 50 ppm and 100 ppm. The nanoparticles reduced ignition delay during combustion, improving thermal efficiency, brake specific fuel consumption, and reducing nitrogen oxide emissions. The study concluded that B20 was better than all blends with the addition of aluminum oxide nano additive to eliminate the biodiesel's drawbacks. The B20 blend with the additive reduced hydrocarbon, nitrous oxide, and carbon monoxide emissions by improving thermal efficiency and specific fuel consumption.
Mustafa Canakci et. al. [17] This study focuses on predicting engine performance and exhaust emissions using five different neural networks for biodiesel blends from waste frying palm oil. The input parameters include PBDF, B100, and biodiesel blends with PBDF. The artificial neural network (ANN) model is used to predict performance and exhaust emissions for biodiesel blends. The fifth network has an R2 value of 0.99, with mean % errors smaller than five except for some emissions. Higher mean errors are obtained for CO, NOx, and UHC. The study suggests that ANNs can be used to predict engine performance and emissions without complex and time-consuming experimental studies. Future studies should investigate the effects of different injection pressures and injection timing on combustion, performance, and exhaust emissions of a diesel engine using ANN methods for biodiesels from different feedstocks.
Deepak Agarwal et. al. [18] The depletion of conventional petroleum resources has led to the search for alternative fuels for internal combustion engines. Vegetable oils, derived from triglycerides, offer a greener alternative to fossil fuels. However, they have issues due to their higher viscosity and low volatility compared to mineral diesel fuel. This research aimed to reduce the viscosity of Jatropha oil by increasing fuel temperature and using blends of Jatropha oil with mineral diesel. The results showed that Jatropha oil is a promising alternative fuel for compression ignition engines, as it can be used directly as a straight vegetable oil without major engine modifications. The study found that the performance and emission parameters of the engine were very close to mineral diesel for lower blend concentrations, but marginally inferior for higher blend concentrations. Thestudy also found that Jatropha oil blends had higher BSFC and exhaust gas temperatures compared to diesel and heated Jatropha oil.
V. Yogesh et. al. [19] This paper investigates the use of a diesel aloevera emulsified fuel (A10) in improving the performance and emission of a non-road diesel engine. The study compared two fuel samples, neat diesel (D100) and A10 (10% aloevera, 89%diesel, 1% surfactant), on a single cylinder Genset diesel engine. Results showed A10 reduced nitric oxide emissions and increased brake thermal efficiency, with a 19.24%reduction in NO emissions and a 9.82% increase in BTE.
K. Balasubramamian et. al. [20] The demand for diesel fuel is slightly increasing, leading to the development of alternative fuels like aloevera oil. Aloevera methyl ester is produced by Transesterification aloevera oil at 65ºC. Experiments on biodiesel and diesel engine performance and emission characteristics show that B25 fuel blends have higher brake thermal efficiency and lower specific fuel consumption. However, NOx emissions increase with higher biodiesel blends. The heat release rate is lower than diesel fuel due to poor pre-mixed combustions.

3.METHODOLOGY

The methodology for the experimental investigation on the performance and emission characteristics of a diesel engine using waste cooking oil biodiesel involves a systematic approach to assess the viability and environmental impact of this alternative fuel source. Firstly, waste cooking oil biodiesel is synthesized through a transesterification process, converting waste cooking oil into biodiesel using a suitable catalyst. The synthesized biodiesel is then characterized for its physical and chemical properties, ensuring it meets the necessary standards for engine use. Subsequently, a diesel engine is selected for experimentation, and a series of tests are conducted using both conventional diesel fuel and waste cooking oil biodiesel. The engine's performance parameters, such as power output, torque, and fuel consumption, are measured and compared under various operating conditions. Emission characteristics, including nitrogen oxides (NOx), carbon monoxide (CO), hydrocarbons (HC), and particulate matter (PM), are also analyzed to evaluate the environmental impact of waste cooking oil biodiesel. Exhaust gas analyzers and particulate matter measurement devices are employed for accurate emissions quantification. To ensure the reliability of the results, the experiments are repeated multiple times, and statistical analysis is applied to assess the significance of the differences observed. The comprehensive methodology aims to provide valuable insights into the feasibility of using waste cooking oil biodiesel as a sustainable and environmentally friendly alternative in diesel engines.

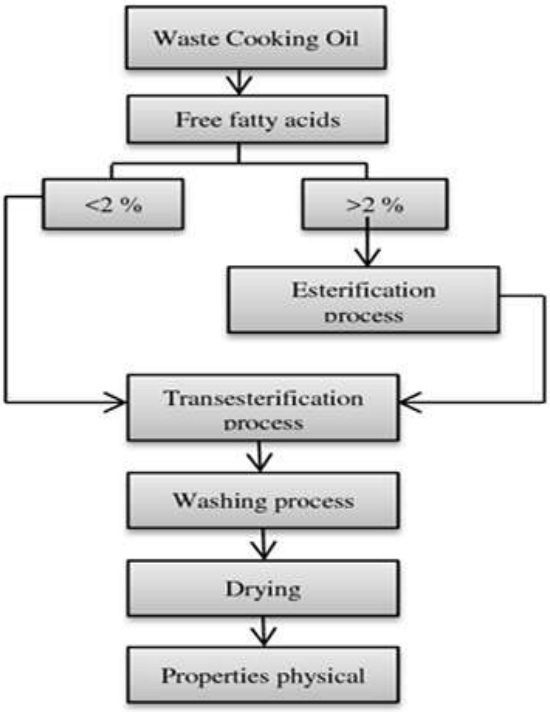


Fig:2 Methodology of the study

PROPERTIES OF BIODIESEL:

The properties of the oils that have been tested are given below in a table-3.1:

Table-3.1: Properties of the biodiesel

PROPERTIES OF OIL	DIESEL	WASTE COOKING OIL BIODIESEL	B20	B30	B40
DENSITY (kg/m3)	838	920	836	862	870
CALORIFIC VALUE kJ/kg	42500	36000	42192	40550	41200
FLASH POINT 0C	70	170	81	92	104
FIRE POINT 0C	56	154	67.7	75.60	88.40
KINEMATIC VISCOSITY cSt	4.237	5.280	4.281	4.425	4.655

4.Experimental setup and procedure:

Calculate full load (W) that can be applied on the engine from the engine specifications. Clean the fuel filter and remove the air lock. Check for fuel, lubricating oil and cooling water supply. Start the engine using decompression lever ensuring that no load on the engine and supply the cooling water. Allow the engine for 10 minutes on no load to get stabilization. Note down the total dead weight spring balance reading, time taken for 20cc of fuel consumption and the manometer readings. Repeat the above step for different loads up to full load. Connect the exhaust pipe to the smoke meter and exhaust gas analyzer and corresponding readings are tabulated. Allow the engine to stabilize on every load change and then take the readings. Stop the engine pulling the governor lever towards the engine cranking side. Check that there is no load on engine while stopping as shown in below Fig.4.

Fig.3: Diesel Engine Setup

5.RESULTS AND DISCUSSIONS

The performance and emission characteristics of diesel engine using waste cooking oil biodiesel have been analyzed and presented as follows.

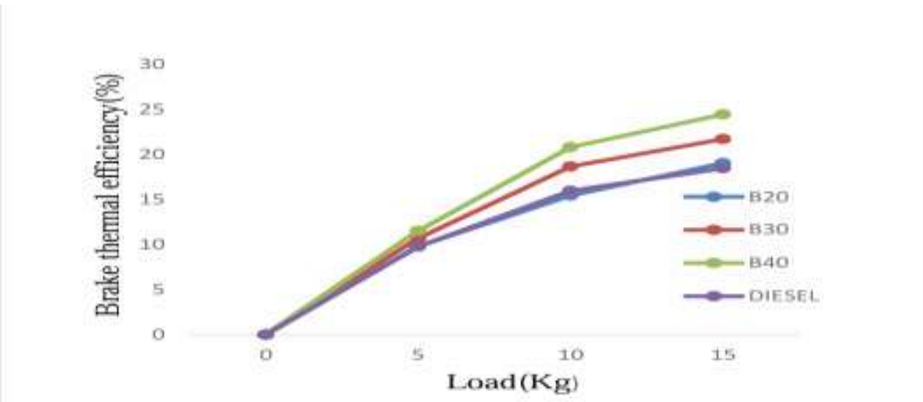
RESULTS:

5.1 PERFORMANCE CHARACTERISTICS:

The experiments are conducted on the four-stroke single cylinder water cooled compression ignition engine at constant speed (650 rpm) with varying Torques. Various performance parameters such as brake thermal efficiency, mechanical efficiency, brake Specific fuel consumption, indicated power are evaluated and discussed below.

5.1.1 BRAKE THERMAL EFFICIENCY

shows the variation of brake thermal efficiency of waste vegetable oil and Diesel blends at different loads. From the graph it is evident that the brake thermal efficiencies of waste cooking oil blends are more when compared to that of diesel but are very near to that of diesel and the variation is similar.



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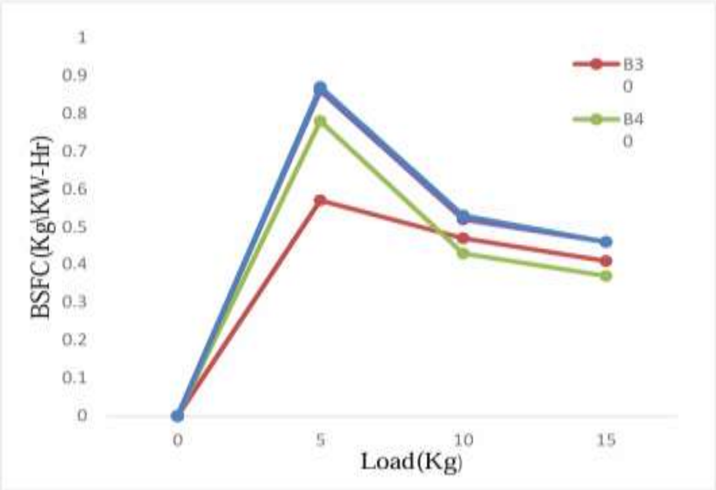
Graph:1 Load v/s Brake thermal efficiency

5.1.2 BRAKE SPECIFIC FUEL CONSUMPTION:

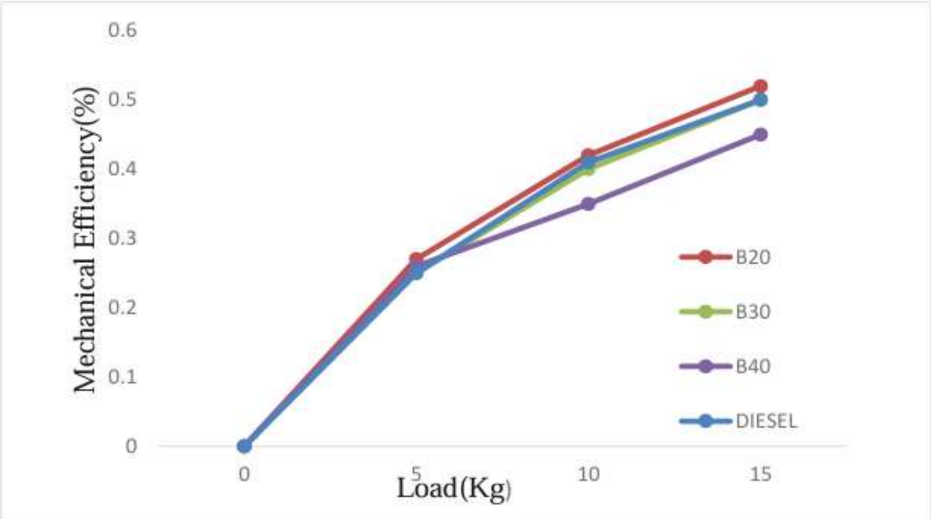
Shows brake specific fuel consumption of engine against load. From the graph it is evident that the BSFC of B20 is higher than Diesel. The Brake specific fuel consumption increases.



Graph :2 Load v/s Brake specific fuel consumption

5.1.3 MECHANICAL EFFICIENCY:

The variation of mechanical efficiency with load is shown in the graph. From graph it is evident that the mechanical efficiency of engine when fueled with diesel the higher than when fueled with diesel-waste cooking oil blends. As the load is increasing mechanical efficiency also increases as seen from the graph. Of the blends tested the B30 Send has good mechanical efficiency.



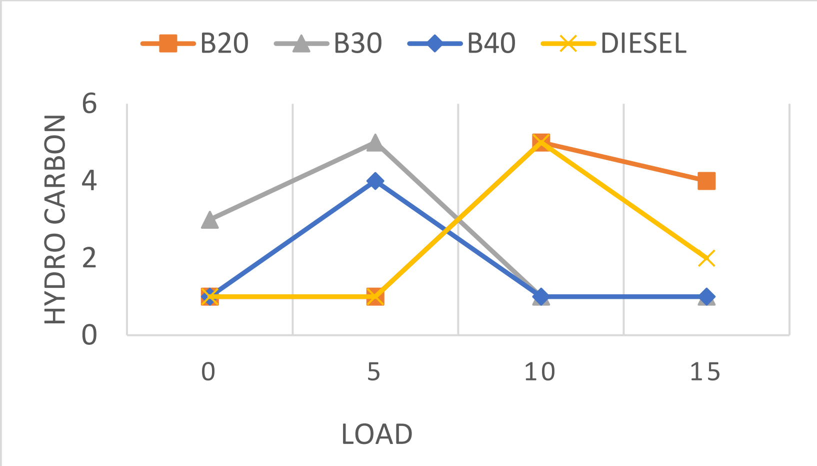
Graph :3 Load v/s Mechanical efficiency

5.1 EMISSION CHARACTERISTICS:

The experiments are conducted on the four stroke single cylinder water cooled compression ignition engine at constant speed (650rpm) with varying load. Various emission parameters like unburned hydrocarbons, carbon monoxide, oxides of nitrogen and unused oxygen are discussed below.

5.2.1 HYDROCARBON(HC)

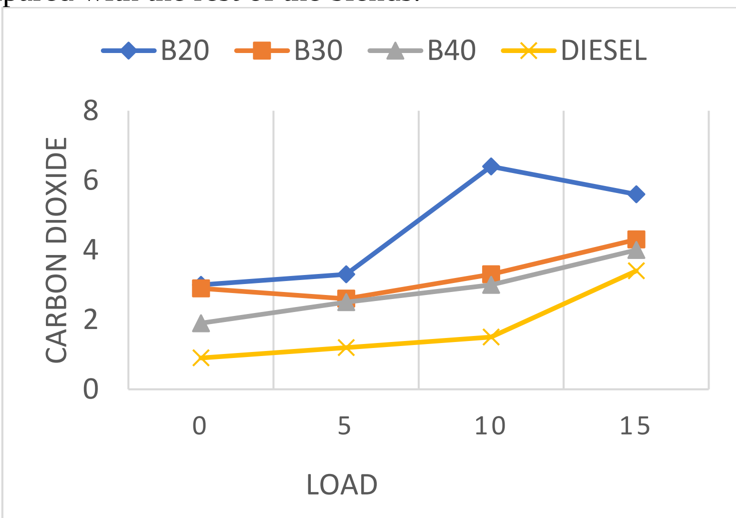
These Graph The variation of HC emissions of Diesel and waste cooking oil blends. From the graph it is seen that the unburnt hydrocarbon emissions of diesel are higher when compared to the Diesel and waste cooking oil blends. As the load is increasing the unburnt hydrocarbon emissions decrease. So, waste cooking oil decrease the HC emissions. Of the blends tested the B40 blend has less Hydrocarbon emissions.



Graph :4 Load v/s Hydro carbon

5.2.2 CARBON DIOXIDE (CO_2)

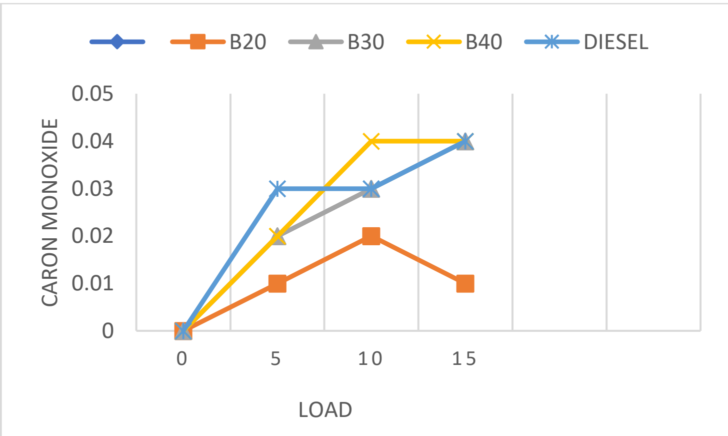
The emissions of Carbon dioxide at different load. From the graph it is understood that the carbon dioxide emissions of waste cooking oil blends are more than pure diesel emissions. The CO_2 emissions for B20 are more compared with the rest of the blends.



Graph :5 Torque V/S Carbon dioxide (Co_2)

5.2.3 CARBON MONOXIDE (CO)

The CO emissions of waste cooking oil blends with load. From the graph it is evident that the Carbon Monoxide emissions of diesel are more when compared with waste cooking oil blends. As the load increases the carbon monoxide emissions go on increases. Of the blends tested the B40 blend has more Carbon monoxide emissions.



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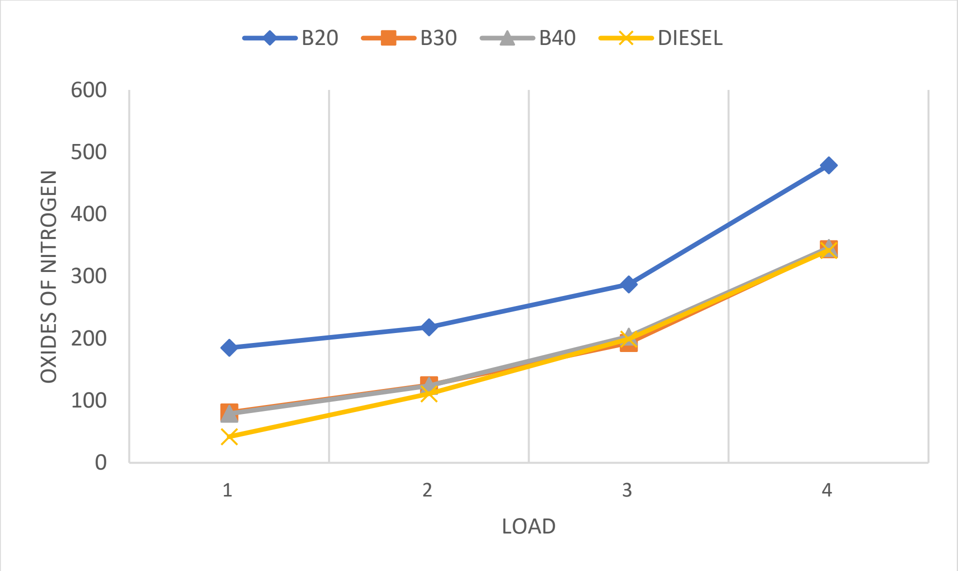
Graph :6 Load V/S Carbon Monoxide

5.2.4 OXIDES OF NITROGEN (NOx)

The variation of No_x emissions of Diesel-waste cooking oil blends with load. From the graph it is seen that No_x emissions of Diesel- waste cooking oil blends are higher than pure Diesel emissions. So, it can be understood that wase cooking oil increase the NO_x emissions. Of the blends tested the B20 blend has higher NO_x emissions.



Graph :7 Torque V/S No_x Emission

DISCUSSIONS:

The experiments are conducted on the four-stroke single cylinder water cooled diesel engine at constant speed (650 rpm) with varying loads of diesel and different blends of waste cooking oil i.e., B20, B30, B40.

The performance parameters such as brake thermal efficiency and specific fuel consumption, Mechanical efficiency and volumetric efficiency were calculated from the observed parameters and shown in the graphs. The other emissions parameters such as exhaust gas emissions such as Carbon monoxide, hydrocarbons, and oxides of nitrogen, carbon dioxide and smoke opacity were represented in the form of graphs from the measured values. The results of comparision of all the blends w.r.t diesel has been determined and the performance and emission characteristics of all blends are given below. Moreover, discussions surrounding this experimental investigation could extend to broader implications, including the economic viability, scalability, and sustainability of waste cooking oil biodiesel production. As the world seeks cleaner and greener energy solutions, the study on waste cooking oil biodiesel adds to the discourse on alternative fuels, potentially paving the way for more sustainable transportation systems.

6.CONCLUSION

The conclusions derived from present experimental investigations to evaluate performance and emission characteristics on a single cylinder four-stroke Compression ignition (C.I) Engine fuelled with diesel – waste cooking oil blends are summarized as follows:-

6.1 CONCLUSION:

- At different loading conditions brake thermal efficiency of B20 blend is more compared to other blends. On blending waste cooking oil with diesel, the brake thermal efficiency of the fuel becomes comparable to that of diesel. This occurs due to the less calorific value of waste cooking oil when compared to that of pure diesel.
- At different loading conditions, mechanical efficiency of B20 blend is more compared to other blends. From graphs obtained we can observe that on addition of waste cooking oil the

mechanical efficiency decreased but the decrease occurs due to the increase in frictional power which reduces the mechanical efficiency.

- At different loads Brake specific fuel consumption of B20 is comparable to that of pure diesel, but the variation is not significantly more. The BSFC values increase with addition of waste cooking oil has less calorific value.
- CO emissions of diesel- waste cooking oil blends are less when compared to that of pure diesel emissions. B40 blend has less CO emissions due to more availability of oxygen in the waste cooking oil which converts CO to CO2.
- Unburnt HC emissions reduce on usage of waste cooking oil. As in B40 there is less amount of waste cooking oil, the HC emissions of this blend are less when compared to other blends and pure diesel. HC emissions reduce as there will be complete combustion of fuel.

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