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Performance and Emission Characteristics of Diesel Engine with Multi-Hole Injector Nozzle using Diesel Tetralin Blends

D.K. Sriram[1] | Dr. M.P. Rangaiah[2]

[1]PG Scholar, Department of Mechanical Engineering, JNTU Anantapur college of Engineering, Ananthapuramu, A.P, India.
[2]Assistant Professor, Department of Mechanical Engineering, JNTU Anantapur college of Engineering, Ananthapuramu, A.P, India.

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ABSTRACT

A substantial increase in the world population is leading to massive energy demand. Industries and automobiles are under immense pressure to meet environmental norms. Out of various resources, coal and gasoline fuels are found to be the primary sources for energy generation and pollution. Although few renewable sources are trying to compensate the energy requirement with minimal pollution, gasoline fuels are degrading the atmosphere aggressively. In this stringent situation, reducing the harmful emission gases from conventional engines is necessary. In this study, six blends of Tetralin and diesel were run on a conventional single-cylinder four-stroke engine with a multi-hole injection nozzle. An analysis is made to compare the performance and emission characteristics of the Tetralin blends and the diesel. 5 Gas analyzer is used to evaluate emission parameters like CO, HC, NO_x and smoke of the engine. This analysis made that Brake Specific Fuel Consumption (BSFC), Brake Thermal Efficiency (BTE) and Mechanical efficiency of the Tetralin blended diesel; and also concludes with the best performed Tetralin blend in each parameter. The maximum brake thermal efficiency is achieved by B20 with minimum brake-specific fuel consumption, among all the blends. B20 performed well, decreasing CO and HC emissions.

KEYWORDS : Tetralin, Diesel, Gasoline fuels, Nozzle, Injector

1. INTRODUCTION

An engine that is used to convert heat into work is called a heat engine. Heat engines are either externalcombustion engines or internal combustion engines.Internal combustion engines are havinghigher efficiency than external combustion engines and emit fewerpollutants in this dieselused as a fuel. The main idea of alternative fuels is a good risein the sector of transportationbecause they will not only assist to the environment quality but also has distinct positivesocioeconomic results. Diesel engines are the most efficientprime movers. From the pointof view of protecting the global environmentand concerns for long-term energy security.itbecomes necessary to develop alternative fuels with propertiescomparable to petroleum-basedfuels. The danger in gasoline and diesel, other fossil fuels except natural gas is that theycontain certain gases that, when released into the air, adversely affect the quality of air andcausedamage to the environment. In present diesel engines, the fuel injectors aredesigned to maintain very higherinjection pressures to acquire better performance results. Themain intention of this design is to decrease exhaust emissions and increase the efficiency of the engine. The fuel injection pressure is inversely proportionalto the droplet size of the fuel.When the fuel droplets are at lower injection pressures the ignition delayperiod increases during combustion. This further leads to an increase in the injection pressure.Engineperformancewillbe reduced since combustion goes to poor condition. When theinjection pressure isincreased the fuel particlesize is decreased. The air and fuel mixtureformation become better from that complete combustion was done in the cylinder during theperiod of ignition. When the injection pressure is high the ignition delay period is shorter. Thehomogeneous mixture leads to an increase in combustion efficiency. The aims of this research not to develop a production-ready fuel injection system, but rather to carry outvarious fuel injection forms on a testengine, to deepen our understanding of diesel combustionand to obtain knowledge useful for combustion improvement.

2. LITERATURE SURVEY

Franz F. Piscine deduced that alcohols seem to be capable of replacing diesel fuel. Alcohols with a high latent heat of evaporation result in lower peak temperatures and spark retardation due to their high flame speeds, which contribute to lower NOx and HC, CO emission levels when the engine is run at low loads.

Nubia M. Ribeiro et al. investigated a variety of subjects formed by using diesel fuel, fuel integrated biodiesel, and ethanol with various additives. Critics suggested that additives reduce exhaust emissions, progress gas viscosity, enhance fuel stability, and proper fuel ignition besides lowering the delay time.

Alan C. Hansen et al. performed a thorough evaluation of a diesel car using ethanol-diesel fuel blends. Evaluators discovered that using diesel-ethanol blends in diesel engines improved engine performance and overall use emissions such as CO and NOX, as well as demonstrated higher performance characteristics.

Rigopoulos et al. Investigated the demonstration of the diesel fuel using diesel alcohol mixtures ranging from 0% to 15% ethanol with a 5% increase. According to the findings, the BSFC and BTE for all blended fuels are higher than for diesel fuel. The results demonstrated that the addition of ethyl alcohol lessens CO, smoke emissions, and engine exhaust temp at medium loads when compared to diesel fuel.

3. EXPERIMENTAL SETUP AND ARRANGEMENT

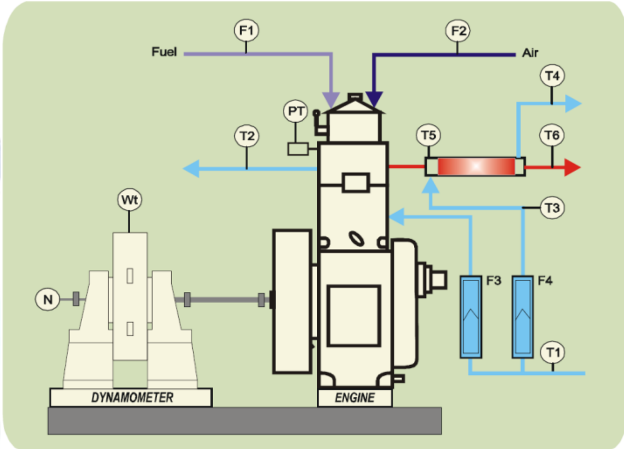

Fig :Schematic diagram of the experimental setup

Table : Schematic diagram variables

Temperature	Water Flow Lpm
Engine Cooling Water Inlet T_1	Fuel Line F_1
Engine Cooling Water Outlet T_2	Air Inlet F_2
Calorimeter Water Inlet T_3	Engine Cooling Water 200 Lph F_3
Calorimeter Outlet T_4	Calorimeter Water 100 Lph F_4
Calorimeter Exhaust Gas in T_5	Pressure Transmitter Pt
Calorimeter Exhaust Gas Out T_6	Crank Angle Encoder N

ENGINE SPECIFICATIONS:

Table: Engine Specifications

Product	Engine test setup 1 cylinder, 4 strokes, Diesel (Computerized)
Product code	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 87.5 mm. 661 cc, CR 17.5
Dynamometer	Type eddy current, water-cooled
Propeller shaft	With universal joints
Airbox	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	5000 PSI, with low noise cable
Crank angle sensor	Resolution 1 Deg, Speed 5500 RPM with TDC pulse.
Data acquisition	NI USB-6210, 16-bit, 250kS/s.

device	
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 DegC, I/P Thermocouple, Range 0–1200 DegC, O/P 4–20mA.

EXHAUST GAS ANALYZER

Fig :Exhaust Gas Analyzer

The working principle used in Exhaust Gas Analyzer is the Non-Dispersive Infrared Technique (NDIR). This hardware is used to quantify an automobile's gas emission density, allowing for the diagnosis of the vehicle's status and reactionary upkeep so that it can provide such a function to prevent air pollutants ahead of time. It is an AVL DIGAS-444 five gas analyzer that can detect CO, HC, CO_2, Oxygen, and NO_x. It also displays the air-fuel ratio and the air surplus rate. When compared to commercially available equipment, it provides accurate and prompt results. Its wide measuring range and high resolution fulfill the criteria of a research project. The Non-Dispersive Infrared Technique (NDIR) is used to calibrate the engine exhaust analyzer for CO, HC, and NO_x.

Measured quantity	Measuring range	Resolution
CO	0-15% vol	0.01% vol
CO_2	0-20% vol	0.01% vol
HC	0-300000 ppm vol	≤2000: 1 ppm vol, >2000: 10 ppm vol
O_2	0-25% vol	0.01% vol
NO_x	0-5000 ppm vol	1 ppm vol

Table :Exhaust Gas Analyzer Specifications

4. OBJECTIVE AND METHODOLOGY

OBJECTIVES

This thesis focused on replacing conventional diesel fuel with tetralin blends. Although tetralin and diesel have closer thermo-physical properties, to achieve the performance and emissions characteristics of the tetralin blends closer to the diesel blends.

The main objective of the study is:

- To evaluate the engine performance using tetralin blends
- To study the variation in emission levels, for tetralin blends.
- To increase the fuel economy by achieving complete fuel combustion using a multi-hole fuel nozzle.
- To reduce the emissions that are caused due to incomplete fuel combustion.

METHODOLOGY

The experimental procedure involves checking the feasibility of the Tetralin blend by determination of properties of the oil, preparation of Tetralin – Diesel blends, determination of properties of blends, running the experimental setup using blends, and validating results, and optimization of obtained results to obtain the optimum blend.

Preparation of Tetralin – Diesel Blends

A blend is prepared by taking a certain known volume of oil and mixing it with diesel to make up one liter of the fuel blend. The mixture is stirred properly to obtain a homogeneous mixture. Tetralin of 50ml is taken and blended with 950ml of diesel to prepare a blend of 5%. This blend is marked as B5. Such blends are prepared with 10%, 15%, 20%, 25% and 30% of tetralin i.e. B10, B15, B20, B25 and B30. A total of 6 blends are prepared and tested for properties.

Table: Blend proportions

BLENDS	BLENDS PROPORTIONS
B5	5% Tetralin + 95% Diesel
B10	10% Tetralin + 90% Diesel
B15	15% Tetralin + 85% Diesel
B20	20% Tetralin + 80% Diesel
B25	25% Tetralin + 75% Diesel
B30	30% Tetralin + 70% Diesel

5.TESTING THE BLENDS ON EXPERIMENTAL SETUP

The feasible blends are chosen one at a time and the fuel reserve of the setup engine is filled with the blend. The engine is started and allowed to run for several minutes to stabilize. Load is applied electrically on the engine in steps, 0%, 25%, 50%, 75%, and 100%. The readings of fuel consumption are noted by taking time for

10ml fuel consumption at each load. This process is repeated for each blend and finally for pure diesel.

As mentioned earlier, the engine is connected to a PCB, and the performance parameters, Brake Power (BP), Indicated Power (IP), Friction Power (FP), Specific Fuel Consumption (SFC), Brake Mean Effective Pressure (BMEP), Indicated Mean Effective Pressure (IMEP), Mechanical and Volumetric Efficiencies are generated into a digital document file by "EnginesoftLV" Engine performance analysis software. The above-mentioned performance parameters can be validated using manual mathematical calculations mentioned below. Cylinder Pressure and Net heat release at various crank angles are also obtained.

Procedure:

1. Ensure cooling water circulation for eddy current dynamometer and piezo sensor, engine, and calorimeter.
2. Start the setup and run the engine at no load for 4-5 minutes.
3. Switch on the computer and run "EnginesoftLV". Confirm that the EnginesoftLV configuration data is as given below.
4. Gradually increase the load on the engine.
5. Wait for a steadystate (at least 3 minutes) and log the data in the "EnginesoftLV".
6. Gradually decrease the load.
7. View the results and performance plots in "EnginesoftLV".

The setup utilizes AVL Digas 444 N Gas Analyzer to measure the emissions, Carbon Monoxide (CO), Carbon Dioxide (CO2), Oxygen (O2), Nitrox Emissions (NOx), Hydrocarbons (HC). The emissions data at various loading conditions for various blends is generated into a digital document. The particulate matter i.e. smoke opacity is measured using AVL Smoke meter 437 C in percentage and converted to FSN using the right factor.

After the results are obtained, graphs are plotted between the load and various performance parameters of each blend and diesel. This helps in analyzing the effects of blends on the engines. Also, graphs are plotted for emissions against load, to compare the emissions with that of diesel. After analyzing all the graphs, an appropriate blend is chosen for real-time application.

6. RESULTS AND DISCUSSION

Depletion of fossil fuels has caused fuel demand all over the world. Emissions from fossil fuels show an impact on the environment and living things. By electric power-driven vehicles, these factors can be reduced, electric power-driven vehicles have various limitations. To meet fuel demand and reduce environmental impact alternative fuels are being considered for partial or complete replacement of fossil fuels. Diesel with tetralin blends is used to find the performance and emission characteristics of the I.C engine and evaluate the results, whether diesel can be partially replaced by the diesel tetralin blends.

PERFORMANCE ANALYSIS :

Brake Thermal Efficiency

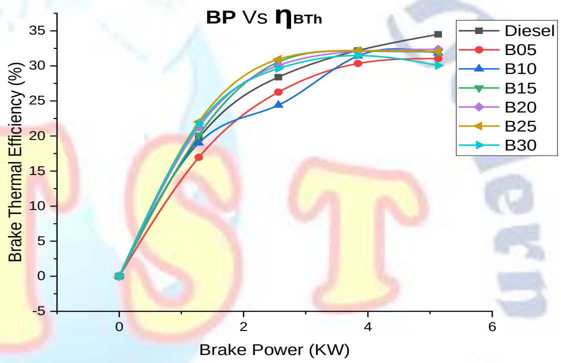

Fig : BP Vs BTE

Brake thermal efficiency BTE of any gasoline engine is desired to be higher to achieve less fuel consumption and harmful exhausts. An increase in the load of the engine will result in increased brake power and decreased BSFC. This condition will unanimously increase the brake thermal efficiency of the engine. Fig. indicated such a condition where the BTE of the engine with various blends is almost at the same spot. Massive ascending of BTE graph took place till the engine reaches 3.5 kW brake power. However, higher BTE is achieved by conventional diesel.

The tetralin blends with multi-hole fuel injection at 200 bars and 5.13 kW Brake Power are inspected. Optimal Break Thermal Efficiency of the blends is achieved by blend B20. However, blend B20 is compared to diesel is 2.11% higher, B05 is 0.98% lesser, B10 is 0.54% lesser, B15 is 0.38% lesser, B25 is 0.07% lesser and B30 2.07% lesser. Blend B20 has the highest Brake Thermal Efficiency among all the blends. Due to an increase in the fraction of tetralin, Brake Thermal Efficiency increases up to blends B20 which is significantly closer to diesel.

Brake Specific Fuel Consumption (BSFC):

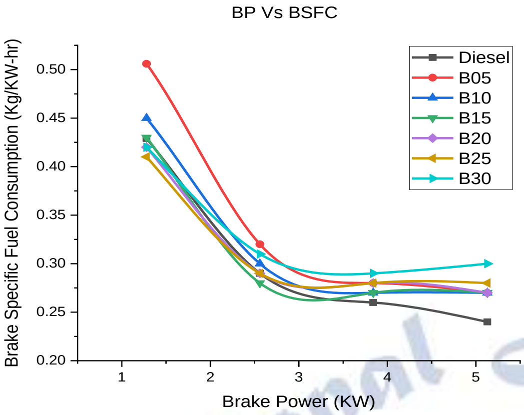

Fig: BP Vs BSFC

The fuel efficiency of any combustion engine is regarded as the Brake specific fuel consumption (BSFC). The efficiency of the engines is said to be higher when that engine has a lower BSFC. Fig. reveals certain relations between brake power and BSFC performed with different blends along with conventional diesel. Massive descent of BSFC is observed till 2.56 kW of brake power. In extension, the graph sustained flattening till 100% load (18 kg) is applied. However, conventional diesel achieved the minimal BSFC by competing with all other six blends, the BSFC of blend B20 is higher than that of diesel

Optimal Brake specific fuel consumption of the blends is achieved by blend B20. However, blend B20 is compared to diesel is 0.03 kg/kW-hr higher, blends (B05, B10, B15) have constant brake specific fuel consumption same as blend B20, B25 is 0.01kg/kW-hr higher and B30 is 0.03kg/kW-hr higher. Blends until B20 have the lowest Brake specific fuel consumption among all the blends. Increase in the fraction of tetralin increases the viscosity of the blends. hence, Brake specific fuel consumption is constant up to blends B20 which is lower among all the blends.

Mechanical Efficiency

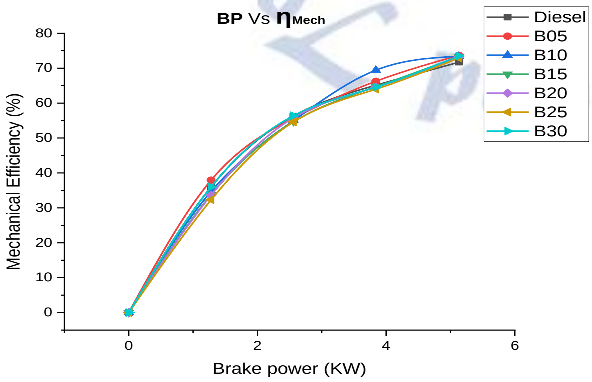

Fig : BP Vs Mech

The mechanical efficiency of any engine is defined by measuring the useful output that occurred with the energy supplied to the engine. The mechanical efficiency tends to increase with the increase in the load and brake power of the engine. Fig. depicted the mechanical efficiency of the engine operated at different loads and with different blends of fuel. The graph exhibited a trend that with the increase in the blend composition, mechanical efficiency is also improved simultaneously. Every blend used for the engine is given better efficiency than conventional diesel.

At full load (18kg) condition Optimal Mechanical efficiency of the blends is achieved by blend B20. However, blend B20 is compared to diesel is 1.55% lower, B05 is 0.53% higher, B10 is 0.17% higher, B15 is 0.08% higher, B25 is 0.35% lower and B30 is 1.24% higher. Blend B20 has 1.55% highest Mechanical Efficiency compared to diesel. Due to an increase in the fraction of tetralin, the calorific value of the blend decreases achieving complete combustion.

EMISSION ANALYSIS

Carbon Monoxide Emissions

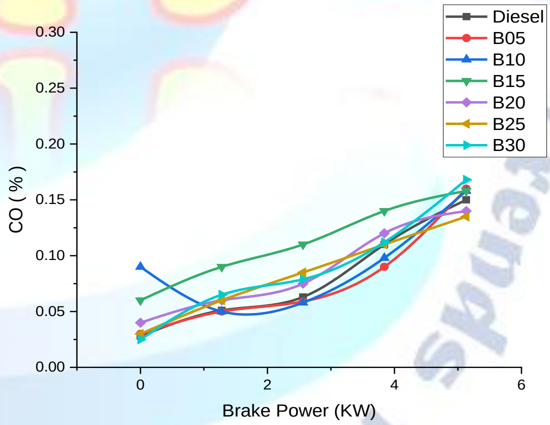

Fig : BP Vs CO

Fig. shows the effect of brake power on the CO emissions with various blends and diesel. The incomplete combustion of any fuel will result in emitting CO gasses. At zero brake power, a higher amount of CO emission is observed with B10.

At full load (18kg) condition Optimal CO Emissions of the blends are achieved by blend B20. However, blend B20 is compared to diesel is 0.1% higher, B05 is 0.2% higher, B10 is 0.018% higher, B15 is 0.018% higher, B25 is 0.05% lower and B30 is 0.28% higher. Examining the graph, B25 and B20 performed well giving lesser emissions of CO (0.015% and 0.01%) higher than diesel among other blends of fuel comparatively. Thus, efficient fuel burning is achieved with B25 and B20.

Carbon dioxide emissions

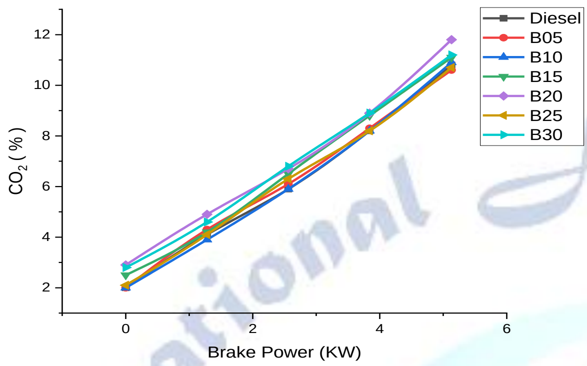

Fig : BP Vs CO_2

Carbon dioxide holds a considerable mass percentage in diesel exhaust gasses. Restricting these emissions in any form will bring a massive change in the overall emissions. Fig. analyzed the performance of chosen blend at full load concerning brake power in the carbon dioxide emissions.

At full load (18kg) condition Optimal CO Emissions of the blends are achieved by blend B20. However, blend B20 is compared to diesel is 1.3% higher, B05 is 1.1% higher, B10 is 1.5% higher, B15 is 1.6% higher, B25 is 1.2% higher and B30 is 1.7% higher. Examining the graph, B20 performed well giving lesser emissions of CO_2 among other blends of fuel and compared to diesel 1.3% lower. Thus, efficient fuel burning is achieved with B20.

Unburnt Hydrocarbons emissions

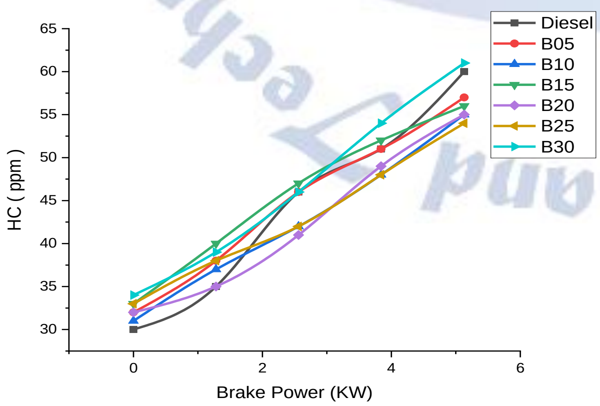

Fig 7.6: BP Vs HC

Hydrocarbons are the key elements in the configuration of chemical fuels. These can be seen in exhaust gasses when the combustion in the chamber done is incomplete. Fig. demonstrates the efficiency of different blends of fuel in emitting the Hydro Carbons in terms of brake power. With the zero-brake power, all the blends have failed with conventional diesel fuel in emitting less HC.

At full load (18kg) condition Optimal HC Emissions of the blends is achieved by blend B20. However, blend B20 is compared to diesel is 5ppm higher, B05 is 2ppm higher, B10 is same as blend B20, B15 is 1ppm higher, B25 is 1ppm lower and B30 is 6ppm higher. Examining the graph, B20 performed well giving lesser emissions of HC among other blends of fuel compared to diesel which is 5ppm lesser. Thus, efficient fuel burning is achieved with B20 with lower HC emissions.

Oxides of nitrogen emissions (NO_x)

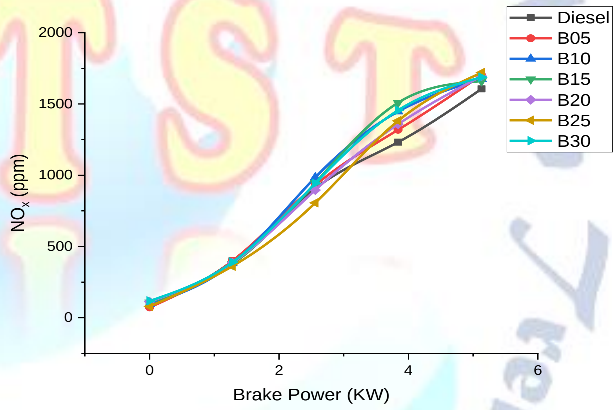

Fig 7.3: BP Vs NO_x

Nitrogen oxide gases are from the family of poisonous emissions that usually occur when the fuel is burned at higher temperatures in the combustion chamber. Brake power is the output power measured at the flywheel of the engine. The above Fig. depicts the relation between the different blends of the fuel and conventional diesel in a significant way. With the increase in brake power, nitrogen oxides tend to increase gradually. Although somewhere at 3.84 kW, NOx emissions have shown subsequent differences, all the emissions of blends and the conventional diesel together are monitored at similar points.

At full load (18kg) condition Optimal NO_x Emissions of the blends are achieved by blend B20. However, blend B20 is compared to diesel is 44ppm lower, B05 is 52ppm higher, B10 is 26ppm higher, B15 is

60ppm higher, B25 is 70ppm higher and B30 is 38ppm higher. Examining the graph, B20 performed well giving lesser emissions of HC among other blends of fuel compared to diesel which is 50ppm higher. Thus, efficient fuel burning is achieved with B20 among all the blends with lower HC emissions.

7. CONCLUSIONS

The engine's brake thermal efficiency increases as the blending proportions increase from B5 to B20 and subsequently reduce for B25 to B30. The maximum brake thermal efficiency is achieved by B20 among all the blends andsignificantly closer to diesel.Brake-specific fuel consumption decreases with brake power increases from blends B5 to B20 and increased later for B25 to B30. At the B20 blend, the minimum brake-specific fuel consumption among all the blends and identical to diesel.The mechanical efficiency is obtained for blend B20, which is 1.55% higher than diesel.Examining the graph, B20 performed well giving lesser emissions of CO (0.14%) among other blends compared to diesel 0.1% higher. Thus, efficient fuel combustion is achieved with B20 at extreme load conditions.The CO_2 emission at full load(18kg) conditions, blend B20 is 1.3% lower than diesel. With the zero-brake power, all the blends have failed with conventional diesel fuel in emitting less HC. However, blend B20 emits fewer HC's at 5.13 kW of brake power. Which is 5ppm lesser than diesel.

It is represented from the results blend B20 produces NO_x emissions, lesser among all the blends and comparatively closer to diesel.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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