Original Research Article

ASSESSMENT OF CI ENGINE PERFORMANCE UTILIZING PALM OIL BIODIESEL BLEND

Abstract

Experiment was explores vegetable oils as potential future fuels for internal combustion engines, particularly compression ignition engines designed for diesel. However, these oils have distinct properties from diesel, requiring modifications for direct use. Integration approaches include adjusting oil properties or adapting engines. Commonly, transesterification aligns oil properties, but using biodiesel often affects engine performance. In this study palm oil biodiesel as a diesel substitute, evaluating engine performance and emissions. In a short-term test, engine performance and emission traits by employing biodiesel blends of 0, 20, and 50 % with diesel at full load. Findings indicated that B20 and B50 exhibited 2.40% and 3.88% lower brake power than pure diesel. Volumetric efficiency percentages were 82.44 for B20, 81.64 for B50, and 82.93 for diesel. Notably, B20 and B50 showed 9.35% and 10.70 % decreased brake thermal efficiency compared to diesel. Interestingly, B20 and B50 displayed 1.09 and 2.44 % higher mechanical efficiency than diesel. Exhaust gas temperature was notably elevated in B20 and B50 blends. Nitric oxide concentrations were 98.74 ppm for diesel, 105.48 ppm for B20, and 111.78 ppm for B50. Carbon dioxide levels decreased by 4.14% for B20 and 7.86% for B50 relative to diesel. Carbon monoxide concentrations were 0.082% for B20 and 0.080% for B50, in contrast to diesel's 0.10%.

Keywords: *Palm Oil, Bio diesel, Performance, Emission, Transesterification, CI engine.*

Introduction

"The demand for petroleum products has expanded as a result of the world's rising industrialization and motorization in recent years. The world's population uses more petroleum than any other single energy source, including natural gas, coal, nuclear energy, and renewable energy sources. About 90% of energy consumption of the world is from petroleum fuels. Petroleum-based fuels come from finite stocks and are only expected to be used for a few more decades" (Velmurugan and Gowthamn, 2012). "However, because of their non-renewable nature, these fossil fuels are projected to be exhausted in the near future. The transportation and electricity generation industries are the biggest consumers of energy. Around the world, the diesel engine plays a crucial role in both of these industries" [6].

"The development of alternative fuels like biodiesels has been accelerated by rising fossil fuel prices, depleting fossil fuel supplies, and environmental concerns. Additionally, the ecosystem has been contaminated by the burning of these fuels. Because of increasingly reduction of fossil-based sources and their negative effects on the environment, the importance of alternative energy sources has become more apparent" (Gojiya et al., 2023). "The finest alternative fuel, considered to be both technically and environmentally acceptable, and widely accessible, is biodiesel. The methyl or ethyl ester of a fatty acid derived from new or used vegetable oil and animal fats is called bio-diesel. Because of its characteristics, palm oil bio-diesel ester is frequently used in India as a synonym for biodiesel, as has been the case with rapeseed oil methyl ester (RME) in Europe" (Pathak, 2004). Straight vegetable oil used as fuel results in a number of issues, including the coking of injector nozzles, piston ring sticking, dilution of the crankcase oil, contamination of the lubricating oil, and more.

"In order to comply with emission requirements without significantly changing engine efficiency and fuel economy, using clean and renewable fuels may be the key. Compression ignition (CI) diesel engines have been utilised with both pure biodiesel fuel (ester-based oxygenated fuel) and biodiesel/diesel fuel mixtures without any engine modifications. In comparison to diesel fuel, biodiesel fuel is created from renewable resources such as vegetable oil or animal fat; it is biodegradable and reduces engine exhaust pollutants. In addition to being a domestic and renewable resource, biodiesel blends are said to significantly cut emissions while offering approximately equal engine performance and fuel efficiency to conventional fuels. Regarding exhaust emission, the use of biodiesel results in lower emissions of unburnt hydrocarbons; carbon monoxide, smoke and particulate matter with some increase in emissions of NOx" (Gaadhe and Mehta, 2019).

Materials and methods

Utilising biodiesel blends, the performance of a compression ignition engine was investigated. The experiment was carried out at the Junagadh Agricultural University's College of Agricultural Engineering and Technology.

Experimental Set Up and Performance Measurement

"The set up would comprise of one engine testing rig with power measurement device, exhaust gas temperature sensors fitted at different places and one digital exhaust gas analyser. The platform had the engine attached. To allow the engine to be fixed with nails or studs, holes were made in the foundation using a hand drill. To reduce noise and vibration, a wooden block should initially be placed between the engine and the platform. To reduce vibration, the engine will be correctly aligned and properly secured with nails or studs all around. For cooling, the engine was connected to an above water supply tank. Different types of thermochemical even biological processes have been adopted to convert biomass into value-added products" (Makavana et. al., 2021).

The system included a single-cylinder, four-stroke engine coupled to a loading dynamometer using an eddy current that was water-cooled. It offered the tools required to measure load, temperatures, airflow, fuel flow, crank-angle, fuel flow, and combustion pressure. Through a high-speed data acquisition device, these signals are interfaced to the computer. Data acquisition is the process of sampling signals that represent actual physical conditions, such as data signals from an experimental setup's sensors, and converting the resulting samples into digital numeric values. These digital numeric values can then be manipulated by an attached computing source based on the inputs or according to pre-programmed instructions from the manufacturer. Data acquisition systems (DAS) typically convert analogy waveforms into digital values for processing. DAS products centrally connect all the components together, such as sensors that indicate temperature, flow, performance, combustion parameters etc. The DAS recorded and saved the average pressure and crank angle readings, peak pressure occurrence, maximum rate of pressure rise, and rate of heat emission as HTML files. This data acquisition software is developed by Technical Teaching (D) Equipment's Pvt. Ltd.

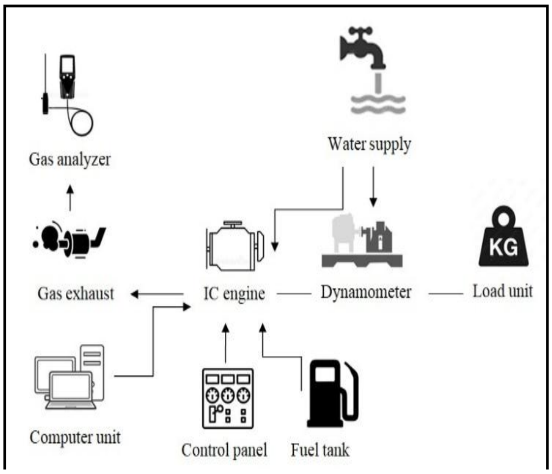

Fig 1: Experimental set up

Fig 2: Pure bio diesel and petroleum diesel fuel

"Diesel fuel was used to assess engine performance and emissions in comparison to mixtures of methyl and ethyl esters of Jatropha oil. A valve linked to the tank allowed the diesel fuel to flow down to the burette. With caution, the engine was hand-cranked and started while a certain volume of water was running through its cooling system. Without any load, the engine was allowed to warm up and reach its operational temperature. The operating temperature would be observed with the help of temperature sensors mounted at the water jacket out let. As the operating temperature is achieved, the engine was loaded with full load. However, the warm-up period would be provided once the load had reached operating temperature and all the heaters designated for it were shining brightly. Then, using the designated instruments, such as the performance measuring unit and exhaust gas analyzer, the observations for the dependent performance and emission parameters were recorded. The increasing awareness of the depletion of fossil fuel resources and the environmental benefits of biodiesel fuel has made it more attractive in recent times" (Dulawat et. al., 2020).

Engine Performance Parameters

Volumetric efficiency (%)

The ratio between the actual weight of air that the engine actually sucked in during the suction stroke and the theoretical weight of air that should have been sucked in had the piston displacement volume been filled with air at atmospheric pressure and temperature.

Specific fuel consumption (kg/kW-h)

The amount of fuel consumed per kW hour in an engine is known as specific fuel consumption, or SFC.

Specific fuel consumption = Total fuel consumption / Power output

$$\text{SFC} = \frac{TFC}{P}$$

Where,

SFC = Specific fuel consumption (kg/kW-h)
TFC = Total fuel consumption (kg/h)
P = Power output (kW)

Brake power (kW)

Power developed by the engine using the diesel fuel and blend fuels under test was calculated from the observed values of current and voltage developed by the generator attached to the engine (Gojiya and Gohil, 2022).

$$\text{Bp} = \frac{V \times I}{1000}$$

Where,

V = Voltage (V) and
I = Current (A)

Brake thermal efficiency (%)

$$\text{Brake thermal efficiency (\%)} = \frac{Brake\ power\ (kW)}{Power\ value\ of\ fuel\ (kW)} \times 100$$

Indicated power (kW)

$$\text{Indicated power (ip)} = \frac{PLAn}{60 \times 10^{12}} \times \frac{x}{2}$$

Where,

P = Mean effective pressure (Pa)
L = Length of stroke (mm)
A = Cross sectional area of piston (mm2)
n = Engine speed (rev/min)
x = Number of cylinders

Mechanical efficiency (%)

$$\text{Mechanical efficiency } (\eta\text{mech}) = \frac{bp}{ip} \times 100$$

Where,

bp = Brake power (kW)
ip = Indicated power (kW)

Indicated mean effective pressure (IMEP)

$$\text{IMEP} = \begin{pmatrix}\text{Avg. pressure during} \\ \text{power stroke } (Pa)\end{pmatrix} - \begin{pmatrix}\text{Avg. pressure during} \\ \text{other stroke } (Pa)\end{pmatrix}$$

Brake mean effective pressure (BMEP)

$$BMEP\ (Pa) = \frac{bp \times 60 \times 10^{12}}{L \times A \times n \times \frac{x}{2}}$$

Where,

bp = Brake power (kW)
L = Length of stroke (mm)
A = Cross sectional area of piston (mm2)
n = Engine speed (rev/min)
x = Number of cylinders

Exhaust Gas Analyser and Emission Measurement

Exhaust gas analyzer (PRIMA FEM-55), which measures temperature in degrees Celsius and the concentration of exhaust gases in parts per million (ppm) or percentage. They can store real-time data, which can then be printed or copied to a computer disc for long-term archival, and they are microprocessor-based. The measurements were performed using several biodiesel blends and all of the chosen load conditions. The electrochemical sensor at the centre of the device senses the gas concentrations around it and turns them into an electrical signal that is sensed by the instrument, amplified, corrected, and shown as a percentage on the LCD. A thermocouple was used to gauge the temperature of exhaust gas.

Engine emission parameters

Engine emission specifications Utilising an exhaust gas analyzer, the temperature and component of the exhaust gas were measured. which used percentage measurements for CO_2 and CO. While the temperature of the exhaust gas and NO were measured in ppm and °C, respectively.

Results and discussion

Effect of various blend on volumetric efficiency of CI engine

Fig.3 it is clear that as percentage of biodiesel is increased in blend, volumetric efficiency was found to be decreasing successively. These findings closely aligned with the results reported by (Gaadhe and Mehta, 2019). The average pod output capacity for groundnut varietyGG-22 was observed as 524.66 kg/h and it was varied from 518.63 kg/h to 531.97 kg/h (Amrutiya at. Al., 2020).

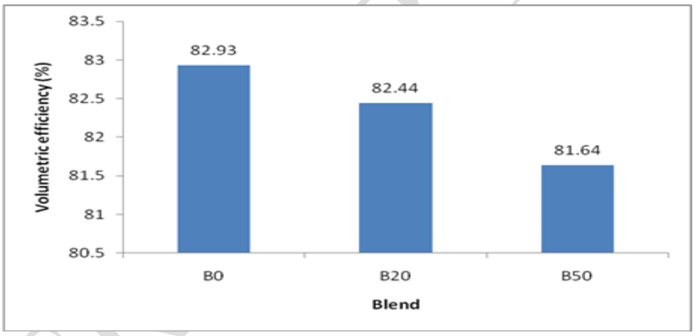

Fig 3: Effect of different blend on volumetric efficiency

Effect of various blends on specific fuel consumption of CI engine

Fig. 4 depicts how various fuel blends affect a particular fuel's usage. Specific fuel consumption was discovered to be rising relative to diesel fuel as biodiesel blend percentages increased.

"Due to the lower calorific values of Jatropha biodiesel compared to diesel fuel, specific fuel consumption for biodiesel is higher than diesel fuel. When it comes to biodiesel and its diesel fuel blends, diesel engine consumes more fuel than diesel fuel to develop the same power" (Agarwal and Agarwal, 2007).

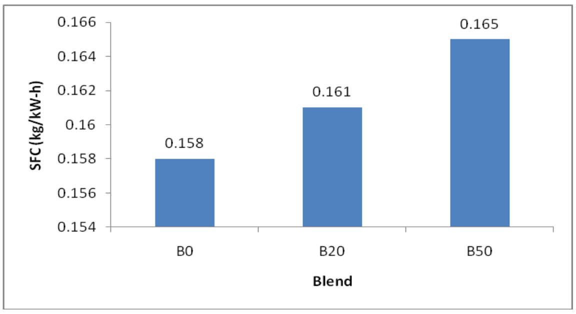

Fig 4: Effect of various blends on specific fuel consumption

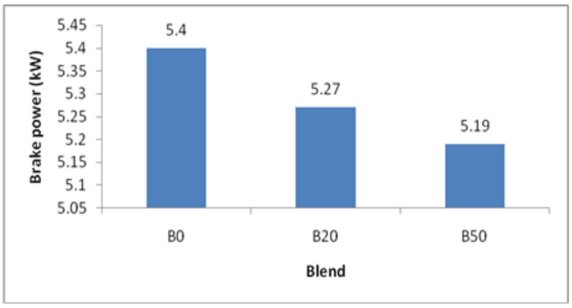

Fig 5: Effect of various blends on brake power

Effect of various blends on brake power of CI engine

The effects of different biodiesel blends on brake power are shown in Fig. 5. “Braking performance was discovered to be less than that of pure diesel fuel as the percentage of biodiesel in the blend rose. This might be because biodiesel blends have less spray properties, improper mixing of fuel–air and incomplete combustion occurred due to higher density of biodiesel blend as compare to pure diesel (B0)” (Nagaraja *et al.*, 2015).

Effect of various blends on brake thermal efficiency of CI engine

Compared to blend B0 (Pure Diesel) fuel at full load, brake thermal efficiency for biodiesel blends B10 and B20 is somewhat lower in Fig. 6. “Due to biodiesel's poor combustion properties—lower calorific value, higher density, higher viscosity, and lesser volatility—biodiesel blends' braking thermal efficiency decreased when compared to diesel fuel” (Patnaik *et al.*, 2015). “Temperature increases, the bio-char yield decreases, this is due to the reason that as the pyrolysis temperature increases then the reaction of devolatilisation occurs, resulted is loss of volatile organic compounds” (Makavana et. al., 2020).

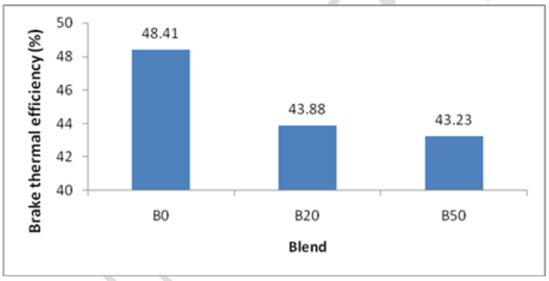

Fig 6: Effect of various blends on brake thermal efficiency

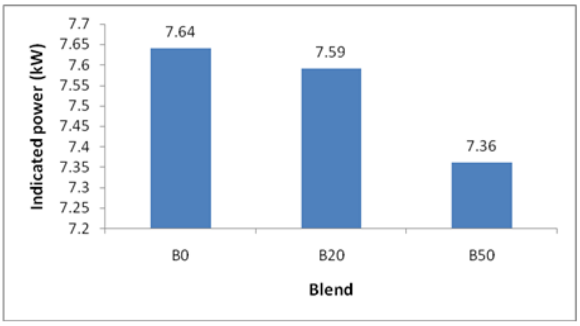

Fig 7: Effect of various blends on indicated power

Effect of various blends on indicated power of CI engine

As the percentage of biodiesel in the mix increases, Fig. 7 demonstrates, the power was discovered to be lower than that of pure diesel fuel. This might be as a result of the fuel's reduced spray characteristics, inappropriate fuel-air mixing, and incomplete combustion brought on by the biodiesel blend's higher density than pure diesel. (Nagaraja *et al.*, 2015).

Effect of various blends on mechanical efficiency of CI engine

Mechanical efficiency was seen to be growing steadily as the percentage of biodiesel in the blend rose, as shown in Fig. 8. The increase in mechanical efficiency was caused by the lubricating effect brought on by biodiesel's higher glycerol content than diesel fuel. “Power weeders are most commonly used machines for removing weeds, to prevent them from competing with main crops. However, these power weeders are power by either petrol or diesel engine. With the shortage of fossil fuel, its unavailability in rural areas and for reducing emission due to burning of fossil fuel” (Kachhot et. al., 2020).

Effect of various blends on indicated mean effective pressure (IMEP) of CI engine

Due to biodiesel's lower volatility than pure diesel, suggested mean effective pressure constantly fell as the percentage of biodiesel in blends grew (Attard et al., 2007).

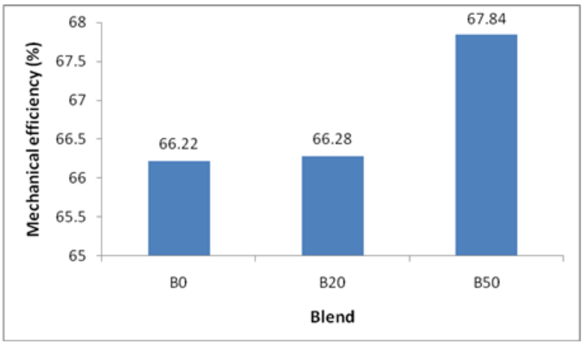

Fig 8: Effect of various blends on mechanical efficiency

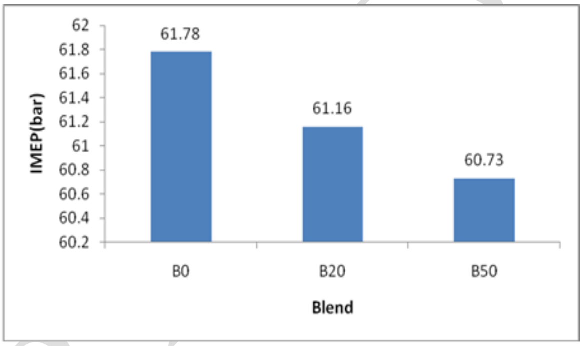

Fig 9: Effect of various blends on IMEP

Effect of various blends on brake mean effective pressure (BMEP) of CI engine

Due to stronger combustion characteristics and higher volatility of diesel fuel, brake mean effective pressure (BMEP) of diesel fuel is higher than biodiesel blend (Fig. 10) (Attard et al., 2007).

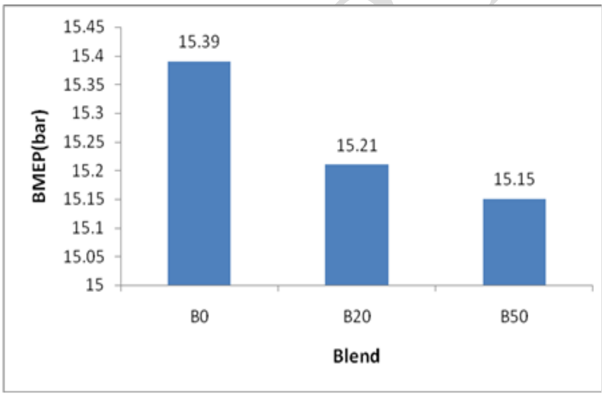

Fig 10: Effect of various blends on BMEP

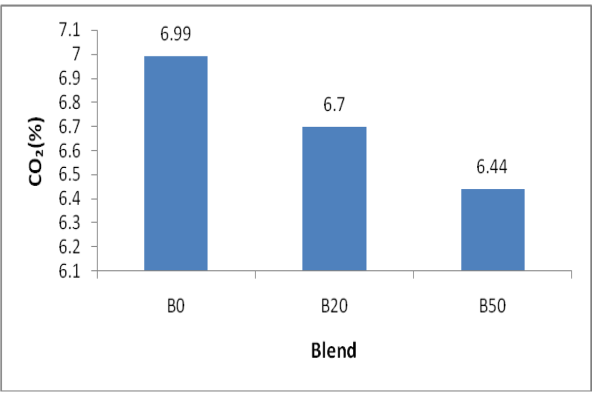

Fig 11: Effect of various blends on CO_2 emission

Emission Characteristics of CI Engine Using Biodiesel Blends

Effect of various blends on carbon dioxide (CO_2) emission of CI engine

Fig. 11 shows that carbon dioxide (CO_2) output gradually decreases as the amount of biodiesel in the blend increases. How well fuel is burned in a diesel engine's combustion chamber is shown by CO_2 emissions. Since the biodiesel blend fuel burns more efficiently than diesel due to higher oxygen content in biodiesel (Hulwan and Joshi, 2011).

Effect of different blend on carbon monoxide (CO) emission of CI engine

"Lower carbon monoxide emissions of biodiesel blends may be due to more availability of oxygen leads to complete oxidation as compared to diesel. Carbon monoxide produced during combustion of biodiesel blends might have converted into CO_2 by taking up the extra oxygen molecule present, thus reduced carbon monoxide formation" (Ganapathy *et al.*, 2011).

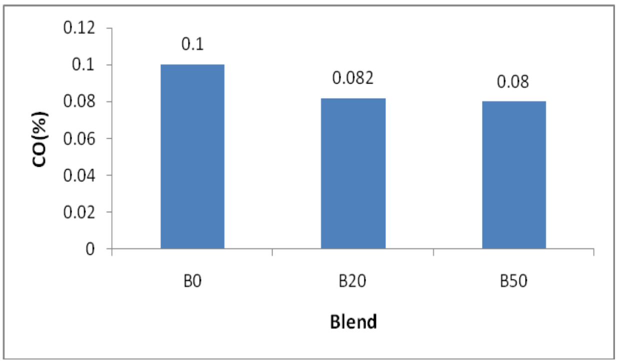

Fig 12: Effect of various blends on CO emission

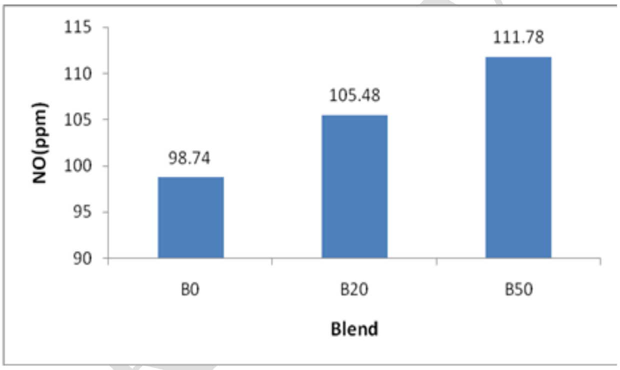

Fig 13: Effect of various blends on NO emission

Effect of various blends on nitric oxide (NO) emission of CI engine

The impact of various fuel blends on nitric oxide (NO) emission is depicted in Fig. 13. Nitric oxide (NO) emissions were discovered to be increasing in comparison to diesel fuel as the percentage of biodiesel rose as a fuel in the blend. Higher NO emissions were produced, particularly at medium engine speeds (about 1500 rpm), due to the higher combustion temperatures and the presence of fuel oxygen in the mix combustion (Ganapathy et al., 2011).

Effect of various blends on exhaust gas temperature of CI engine

It is evident from Fig. 14 that the temperature of the exhaust gas increased in comparison to diesel fuel as the percentage of biodiesel in the fuel blend increased. A higher exhaust gas temperature was observed for biodiesel blends than for fossil diesel for the entire engine load due to the poor combustion characteristics. This may be because more gasoline is burned to match the higher load demand, which raises the temperature inside the engine cylinder (Buyukkaya, 2010).Thermal properties become useful for each and every step for determining fuel potential from agricultural residues (Makavana et. al., 2018).

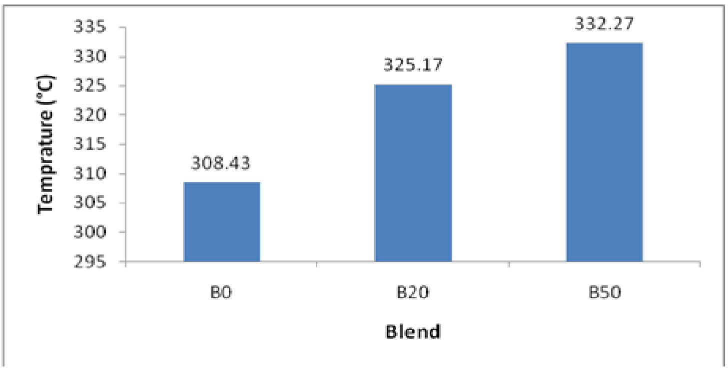

Fig 14: Effect of various blends on exhaust gas temperature

Conclusions

The Experiment yielded significant conclusions regarding various aspects. The properties of blends, including density, viscosity, and flash point, were found to be higher, with a calorific value ranging from 0.85 to 0.9 times that of diesel. Notably, the lowest emissions of carbon dioxide (CO_2) and nitric oxide (NO) were achieved without blending, under a 14:1 compression ratio and full load conditions, registering values of 3.40% and 48.66 ppm, respectively. On the other hand, the maximum brake mean effective pressure of 26.80 bar was observed with a 20% blend, utilizing a 14:1 compression ratio at full load. When there was no blending, a 14:1 compression ratio, and full load operation, the experiment recorded impressive metrics: a maximum brake power of 9.00 kW, a peak brake thermal efficiency of 63.52%, a maximum indicated power of 11.50 kW, a top indicated mean effective pressure of 79.66 bar, and a minimum specific fuel consumption of 0.123 kg/kW-h. In terms of mechanical efficiency and energy consumption, the highest figures of 78.37% and 80.52 MJ/h, respectively, were achieved under no blending, employing an 18:1 compression ratio, and operating at full load. Moreover, the experiment established that employing a 50% blend, a 12:1 compression ratio, and operating under a no-load condition resulted in the lowest fuel cost, amounting to ₹ 71.34 per hour. This study revealed that the brake thermal efficiency and brake specific fuel consumption of blends were lower and higher, respectively, in comparison to diesel. This can be attributed to the blends' higher viscosity and lower calorific value. Additionally, the blends demonstrated a lower presence of CO_2 and CO emissions than diesel due to more efficient fuel combustion within the cylinder. As a conclusion, the findings highlight that a blending ratio of 20% provides optimal values for both performance and emission characteristics.

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