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Detailed Study of Performance and Emission Characteristics of Diesel Engine Fuelled with Biodiesel and Additive

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Abstract

The usage of biofuels namely alcohols and biodiesel leads to lower efficiency and higher NO emissions than diesel. The objective of this study is to reduce the emissions and enhance the performance from neat coconut oil biodiesel. To begin, the Diethyl ether, (Oxygenated Additive, OA) is blended to transesterified coconut oil biodiesel (CBD100). OA is varied in CBD at 5 and 10% on a volume basis. Results revealed that the addition of OA to CBD results in no phase separation at all working conditions. Further, adding 10% of OA to CBD lower CO (1.7%), Smoke (2.1%), NO (2.7%) and HC (1.9%) emission than neat CBD. In addition, efficiency increased (1.2%) and fuel consumption lowered (1.3%) by blending OA to CBD at all loads.

Keywords: Coconut oil; Bio-diesel; DEE; Additive; Performance..

1. Introduction

Global warming and reduction in air quality lead to the search for a new alternative to fossil fuels. Much research works are paying attention to lowering the emissions from engines (

Devarajan et al., 2019b, 2019c). Research on lowering on emissions is classified on adjustment on engines and the fuel. Engine design modifications are tedious. Modification on the system like EGR, SCR, Altering compression-ratio, injection timing is viable techniques to lower the emissions (Appavu, 2018). However, these techniques shall not be practised in on-road heavy-duty vehicles. Hence fuel modifications shall be appealing perception to lower emissions from engines. Fuel modifications namely blending with oxygenated fuels such as Biodiesel (BD), alcohols, Ignition enhancers are mainly concentrated to achieve the objective of lowering the emissions. BD as its nature varies its properties with time. Many works in the past have proved higher NO emissions with lower performance for BD than diesel (Devarajan et al., 2019). Alcohols by blending with diesel generate miscible issues and hence are not widely accomplished. However, diesel and BD doped with ignition enhancer shall be an interesting ad noteworthy concept to lower its snag (Sudalaimuthu et al., 2019).

Ignition enhancer namely DTBP, DME, DME, DEE and so on are widely used practised by blending with diesel, BD and its blends. Minority literature employed these enhancers in diesel/BD blends to limit emissions. Ganesan et al (2019) employed enhancer (DTBP) to BD/diesel blends. 10-20% of DTBP was mixed with BD/diesel blends to subordinate its emissions. They achieved 3.3% smoke, 2.7% CO, 1.7% NO emissions by adding 10% of DTBP to BD/diesel blends. Devarajan (2018) employed enhancer (DMC) to BD/diesel blends. 10-20% of DMC were mixed with BD to lower its emissions. He achieved 3.6% smoke, 7.4% CO, 4.7% NO emissions by adding 10% of DMC to BD. Joy et al (2019) employed enhancer (DME) to cashew nut BD/diesel blends. 10-20% of DMC were mixed with BD/diesel blends to assistant its emissions. They achieved 8.4% smoke, 3.4% CO, 8.8% NO emissions by adding 10% of DMC to BD/diesel blends. Past literature revealed that no emission reduction work was focused on DEE (OA) with neat coconut oil biodiesel (CBD100).This work fills the space on using enhancer in neat biodiesel. The aim of this study is to reduce tailpipe emissions and improve the performance of CBD100 by blending OA at 5 and 10% volume.

2. Materials and methods

2.1. Experimental setup

This study employed a single-cylinder, the four-stroke air-cooled diesel engine is used. The engine is being equipped with a rated power of 4.2 kW. The compression ratio of the engine is 17.5:1. The engine has a bore diameter of 87.5mm and a stroke length of about 110mm. Speed of the engine is maintained constant at the rate of 1500 rpm. The specification of the engine is listed in Table 1. AVL Exhaust gas analyzer is used to measure tailpipe emissions.

2.2. Test fuels

Base transesterification was in use for the biodiesel production from raw coconut oil (Sivamurugan and Devarajan, 2018). 500 g of coconut oil was mixed with and 2.5% (weight %) of KOH and methanol at a ratio of 6:1 and heated till 75 °C in the conical flask. Then the mixture was stirred constantly at 85 °C for reaction time 60 minutes and kept uninterrupted for phase separation. The upper layer was of CBD100 while glycerol was settled at the base. The obtained biodiesel contains 24.2 % mass of Stearic acid, 26.8% mass of Oleic acid, 37.2% of Linoleic acid (18:1) and 12.8 of Linoleic acid (18:2). Neat coconut biodiesel (CBD100) and the blends of the DEE-biodiesel (OA05CBD95 and OA10CBD90) were fuelled separately. The fuel properties of CBD100, OA05CBD95 and OA10CBD90 are established as per ASTM standards and are listed in Table 2.

3. Results and discussion

3.1. Carbon monoxide and Hydrocarbon emissions (HC):

Figure 1 portrays the variation of CO and HC emission with the load for CBD100, OA05CBD95 and OA10CBD90. CO and HC for all fuels develop with the load. With load increase (0-100%), there is a rise in fuel supplied. This leads to a rich mixture causing elevated CO and HC emission (Yuvarajan et al., 2016). CO emissions vary from 1 -3 g/kWh whereas, HC emissions varies from 0.15-0.4 g/kWh. OA at 10% blending showed 1.7 and 1.9% reduction in CO and HC emission respectively at 0-100% load. DEE is basically an oxygen-rich fuel which credits surplus oxygen to CBD causing uniform oxidation and lower emissions. DEE also optimizes the fuel in an improved manner leading to improved combustion and lower emissions (Justin et al., 2018). CO emissions for CBD100, OA05CBD95 and OA10CBD90 are 2.9, 2.1 and 1.9 g/kWh whereas; HC emissions for CBD100, OA05CBD95 and OA10CBD90 are 0.39, 0.35 and 0.28 g/kWh at 100% load.

3.2. Nitrogen and smoke emissions

Figure 2 portrays the variation of NO and smoke emission with the load for CBD100, OA05CBD95 and OA10CBD90. NO emissions depend on temperature attained in the cylinder. Smoke emissions depend on the air in the cylinder. NO, and smoke emissions for all fuels develop with the load. With load increase (0-100%), there is a rise in fuel supplied. This leads to a rich mixture causing elevated NO and smoke emission. NO emissions vary from 6 -13 g/kWh whereas, Smoke emissions varies from 0.2-1.4 BSU. DEE at 10% blending showed 2.7 and 2.1% reduction in NO and smoke emission respectively at 0-100% load. This reduction is achieved by the latent heat of vaporization (NO) and oxygen-rich mixture nature (Smoke) of DEE. Latent heat lowers the combustion temperature and oxygen-rich nature promotes combustion (Ramakrishanan et al., 2019). Higher oxygen content enhances the combustion leading to better atomization and burns the fuel in the leaner environment leading to lower NO and smoke emissions. NO emissions for CBD100, OA05CBD95 and OA10CBD90 are 13.1, 12.5 and 12.1 g/kWh whereas; Smoke emissions for CBD100, OA05CBD95 and OA10CBD90 are 1.39, 1.27 and 1.21 BSU at 100% load.

3.3. Brake Thermal Efficiency (BTE) and Brake specific fuel consumption (BSFC):

Figure 3 depicts the variation of BTE and BSFC with the load for CBD100, OA05CBD95 and OA10CBD90. BTE and BSFC are inversely comparative. Fuel with higher BTE ends up with lower BSFC. BTE varies from 5 -29% whereas, BSFC varies from 0.29-0.42 kg/kWh. DEE at 10% blending showed 1.2 increases in BTE with and 1.3 % reduction in BSFC respectively at 0-100% load. This improvement in BTE and BSFC for OA05CBD95 and OA10CBD90 may be attributed to better atomization, vaporization, high volatility, low viscosity and higher energy content of BD and AO blends, resulting in rich combustion (Devaraj et al., 2018). Further, this shall also be attributed to the overindulgence oxygen molecule that results in better combustion of OA05CBD95 and OA10CBD90 than CBD100 (Siva et al., 2018). BTE for CBD100, OA05CBD95 and OA10CBD90 are 27.4, 28.3 and 28.7% whereas; Smoke emissions for CBD100, OA05CBD95 and OA10CBD90 are 1.39, 1.27 and 1.21 kg/kWh.

4. Conclusion

The objective of this study is to reduce the emissions and enhance the performance from neat coconut oil biodiesel. Hence, Diethyl ether which acts as oxygenated Additive is blended to transesterified coconut oil biodiesel at 5 and 10% on a volume basis and tested at different load conditions and the following conclusions are derived.

- Blends containing a higher percentage of DEE with BD showed 1.7 and 1.9% reduction in CO and HC emission respectively at all loads than neat BD. This is attributed to uniform oxidation during the combustion process by DEE.
- DEE at 10% blending showed 2.7 and 2.1% reduction in NO and smoke emission respectively at all loads which are achieved by the latent heat of vaporization and oxygen-rich mixture nature of DEE.
- This improvement in BTE and BSFC is achieved for the blends containing a higher percentage of DEE with BD. This is due to better atomization, vaporization, high volatility, low viscosity and higher energy content of BD and AO blends.

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Disclosure Statement:

No potential conflict of interest

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Table 1. Specification of Experimental Setup

Cylinder	Single
Rated power	5.5 kW
Rated speed	1800 rpm
Bore diameter (D)	87.5 mm
Stroke (L)	110 mm
Compression ratio	17.5:1
Injection Timing	17°bTDC
Injection pressure	200 bar
Cooling	Air cooled

Table 2. Properties of the Tested fuels

PROPERTIES	BD100	DMC5BD95	DMC10BD90	METHOD
Density @ 15°C (gm/cc)	0.88	0.86	0.84	ASTM
Kinematic Viscosity @40°C	4.2	4.1	3.9	ASTM D445
Calorific Value (kJ/kg)	38698	38785	39114	ASTM D240
Flash point (°C)	148	151	154	ASTM D93
Cetane Number	55	58	61	ASTM D976

Table 1. Specification of Experimental Setup

Table 2. Properties of the Tested fuels

Figure 1. Difference in CO and HC emissions with load

Figure 2. Difference in NO and Smoke emissions with load

Figure 3. Difference in BTE and BSFC with load

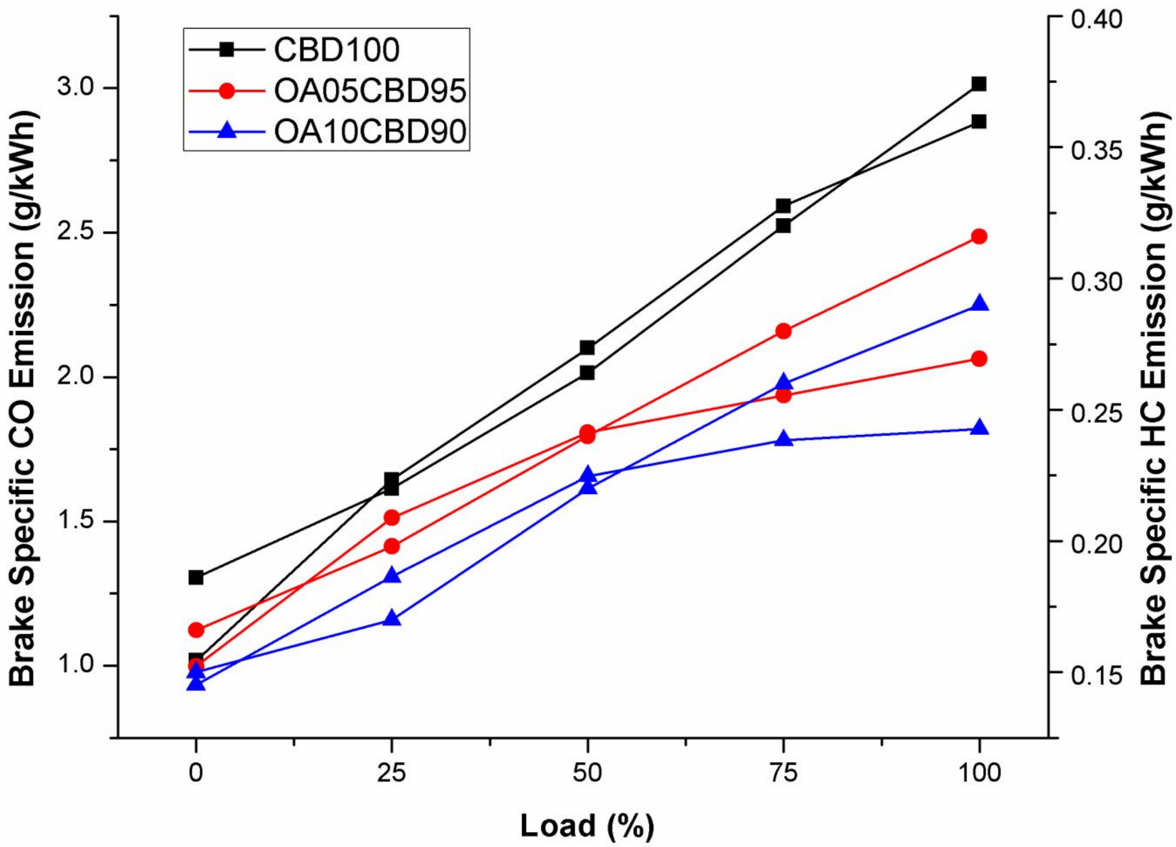

Figure 1. Difference in CO and HC emissions with load

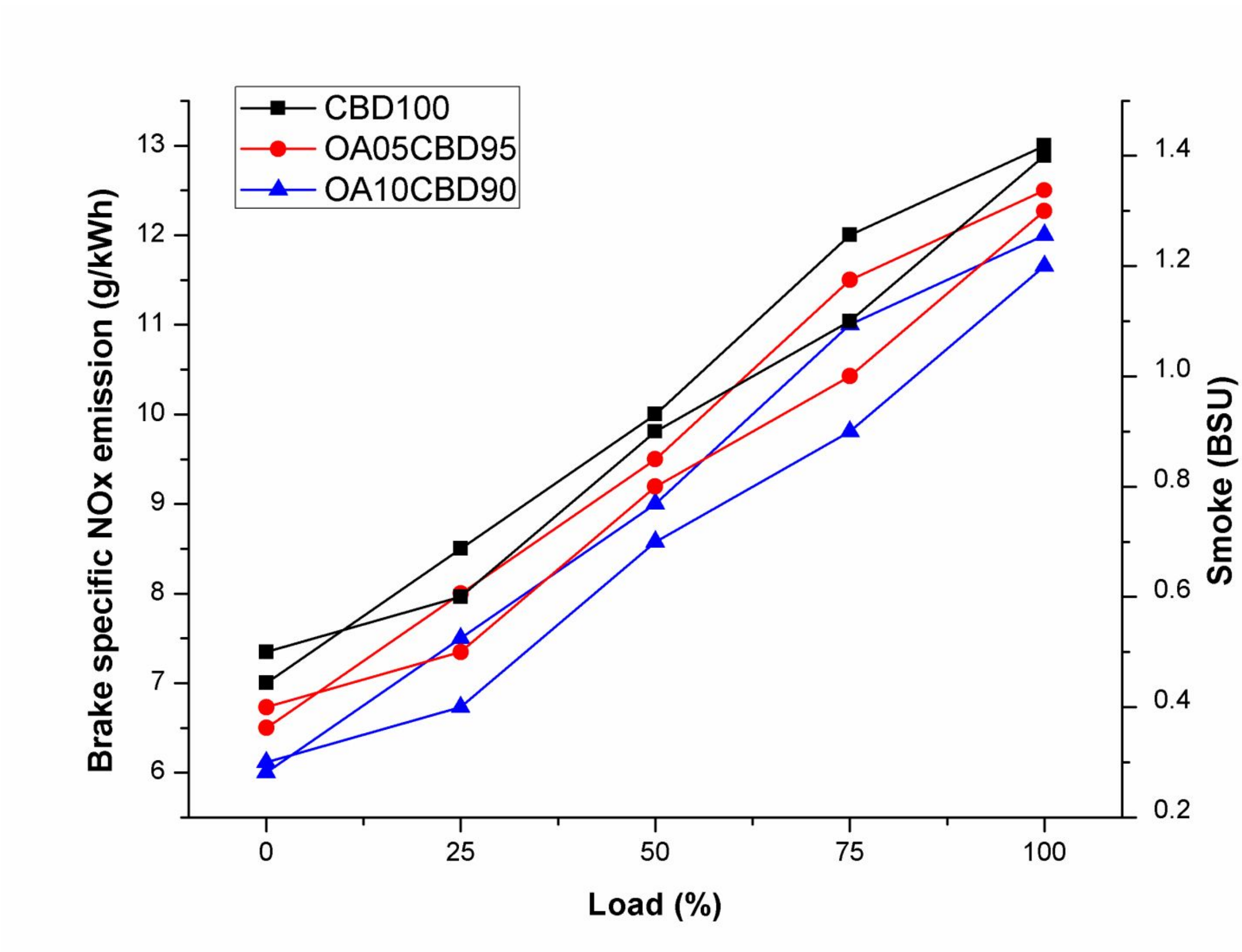

Figure 2. Difference in NO and Smoke emissions with load

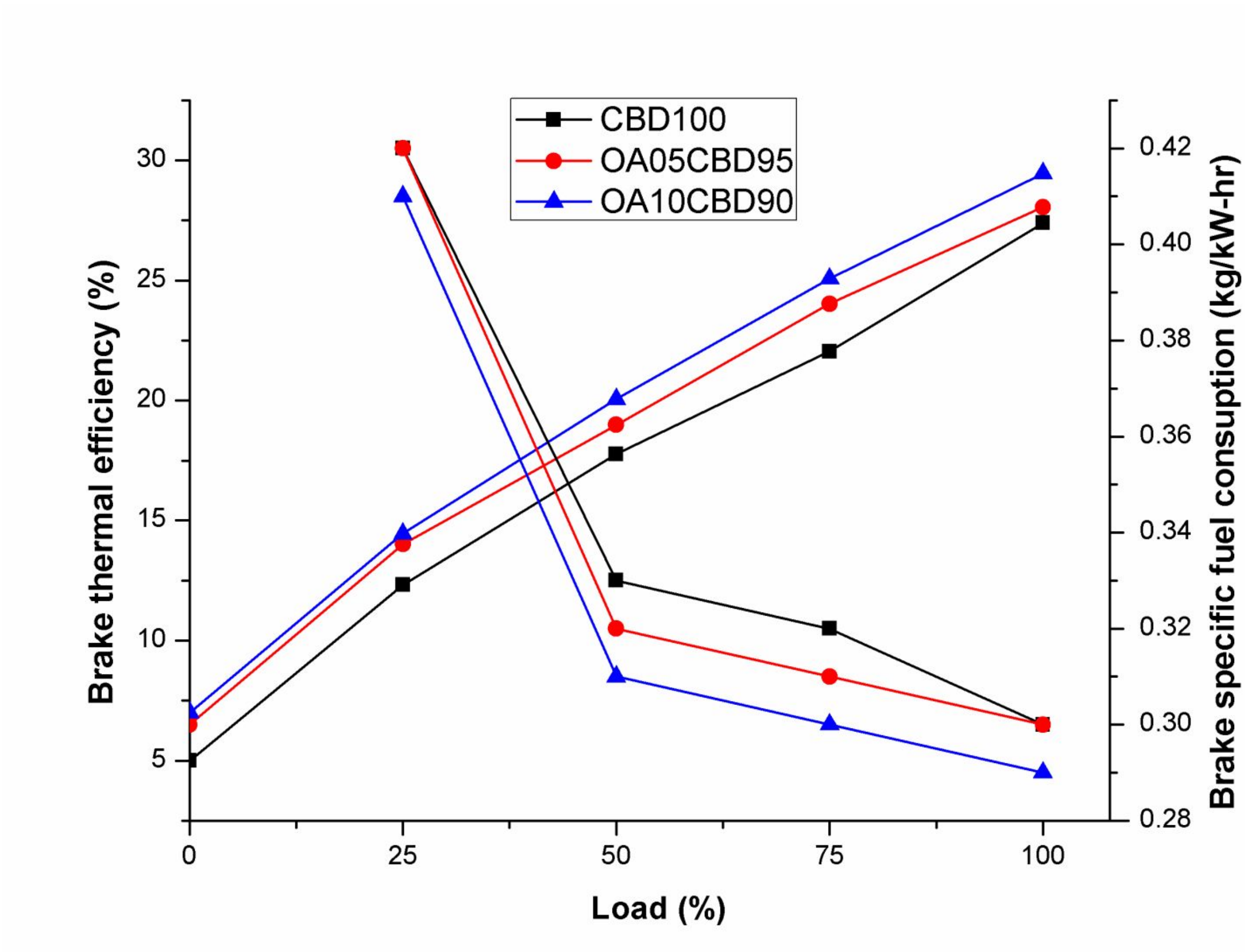

Figure 3. Difference in BTE and BSFC with load