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Experimental Investigation on the Influence of Gas-to-Liquid (GTL) Fuel in Reduction of the Hazardous Emission Parameters of the Combined Blend of Diesel-Biodiesel

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Abstract. This study comprises of a comparative analysis of the blends of GTL fuel (G20) and palm biodiesel (P20) with diesel, including a combined blend (DPG20) of palm biodiesel (PBD), GTL and diesel (DPG20), in the context of harmful environment pollutants and fuel properties. This combined blend was selected to aggregate the promising properties of these two alternative fuels, which is a pioneer study involving GTL fuel. All of the blends had been investigated in a four cylinder compression ignition engine at different load-speed conditions. PBD and P20 showed improved fuel properties than their crude oil, but DPG20 and G20 showed the most promising properties than all test fuels. The engine emission test results revealed that G20 showed slight reduction in NO_x about (9.06%), but significant reduction in CO about (25.96%), HC about (27.49%) and smoke about (19.18%), respectively, when compared to diesel. Referring to the same test conditions, on average, P20 and DPG20 demonstrated reduced CO about (18.1-23.47%); HC about (11.58-23.62%) and smoke about (11.1-15.81%), but increased NO_x about (1.13-3.51%), respectively than those of diesel. In comparison to P20, DPG20 showed improvement in all emission test parameters.

Keywords: GTL fuel, biodiesel-diesel blends, fuel characteristics, exhaust emission.

1. Introduction

Biodiesel and GTL fuel can be considered as prospective future transportation fuels. Palm oil can be regarded as a potential feedstock for biodiesel production because of its higher oil yield and the compliance of the produced biodiesel from its crude oil with the US ASTM D6751 and European Union EN 14214 biodiesel standards[1], [2]. GTL fuel possesses high CN, virtually zero sulphur and negligible amounts of aromatic, and also demonstrates significantly lower emission than diesel and biodiesel [3]-[5]. Some recent studies have been reported regarding the combined blends two alternative fuels (GTL fuels or biodiesels) with diesel with an aim for further improvement of the fuel properties and engine exhaust emission results. Sanjid et al.[2] studied two combined blends of palm–Jatropha biodiesel with diesel in a multi-cylinder diesel engine at different engine speeds. PBJB5 and PBJB10 biodiesels showed higher BSFC (7.55 -9.82%), lower output power, whereas, lower CO about (9.53-20.49%) and lower HC about (3.69-7.81%), respectively, than diesel. Habibullah et al.[1] studied the combined blends (PB15CB15) of palm-coconut biodiesel with diesel in a single cylinder diesel engine. PB15CB15 showed improvement in brake power and also reduction in BSFC and NO_x emissions than CB30. When compared with PB30, PB15CB15 showed reduction in CO and HC emissions, with improved brake thermal efficiency. Though only a few studies regarding the combined blends of two biodiesel with diesel have been reported, no study has been performed using blends combining biodiesel, GTL fuel and diesel till now. The objectives of this study are to improve engine exhaust emission characteristics, by using a combined blend of biodiesel (PBD), GTL fuel and diesel, while comparing to the traditional blends (20% by vol.) of biodiesel-diesel and GTL-diesel. This study of the combined blend will ensure the existing emission benefits of biodiesel, along with the improved fuel

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properties and engine emission parameters of GTL fuel and diesel. All of the test fuels were investigated in the context of fuel properties and engine exhaust emission characteristics in constant load with variable speed test conditions.

2. Experimental Set up and Procedures

2.1. Fuel blend preparation

In this study, three blends had been prepared as sample fuels. 20% by vol. of for each of PBD and GTL fuel were mixed with 80% by vol. of diesel, and were designated as P20 and G20, respectively. The third blend contained 50% diesel, 30% biodiesel and 20% GTL fuel and named as DPG20. The test rig schematic is depicted in Fig. 1. The specifications of the test engine and experimental conditions are depicted in Table 1 and Table 2. Engine test was performed at full load and with variable speed within the range of 1000-4000 rpm, at an interval of 500 rpm. For recording the engine test data REO-dCA data acquisition system was incorporated. For exhaust emission analysis, an AVL DICOM 4000 gas analyser was used to measure the concentration of CO, HC and NO_x. Opacity for smoke measurement was measured with AVL Di-Smoke 4000.

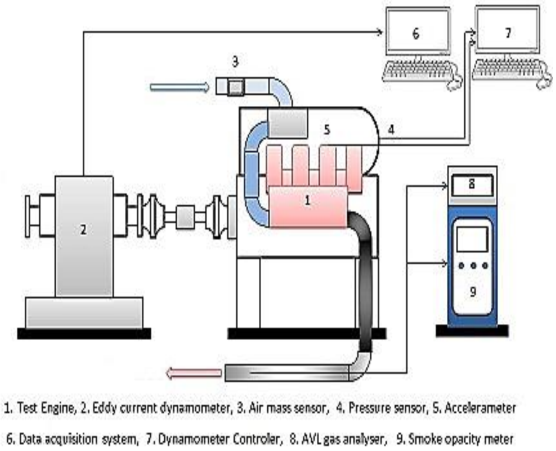

Fig. 1: Experimental Set-up

Table 1: Engine Specification

Engine type	4 Stroke diesel engine
Number of cylinders	4 in-line, longitudinal
Cylinder bore * stroke	91.1 x 95 mm
Displacement	2477 cc
Compression ratio	21:1
Combustion chamber	Swirl type
Rated Power	65 kW at 4200 rpm
Torque	185 Nm, at 2,000 rpm
Valve mechanism	Single overhead camshaft (SOHC)
Injection pressure (kg/cm^2)	157 bar
Aspiration	Turbo charged
Fuel system	Distributor type injection pump
Cooling system	Radiator cooling
Lubrication system	Pressure feed, full flow filtration

3. Results and Discussion

Table 2: Emission analyser Specification

AVL Exhaust Gas Analyser	Method	Measured component	Range	Resolution
	Non-dispersive infrared	CO	0.10% vol.	0.01 vol.%
	Non-dispersive infrared	Unburned HC	0-20000 ppm Vol	1 ppm
	Electrochemical	NO_x	0-5000 ppm Vol	1 ppm
Smoke opacimeter	Photodiode detector	Opacity %	0-100%	0.10%

Table 3: Fuel properties of the blends

Properties	Diesel	P20	G20	DPG20
Density Kg/m^3	829.6	837	815.8	826.2
Kinematic viscosity at 40 ℃ (mm^2/sec)	3.07	3.68	3.03	3.58
Calorific value	44.46	43.71	45.026	43.88
Cetane number	49	54	62	58
Flash Point (℃)	69.5	78.5	83.5	90.5

3.1. Fuel property analysis

Table 3 features tested fuel properties of the test fuels. Among the test fuels, P20 and DPG20 showed higher density and viscosity, whereas, G20 showed lower values of these two parameters, than those of diesel. P20 and DPG20 demonstrated about 19.8% and 16.61% increased kinetic viscosity than diesel, whereas, G20 showed 1.66% lower values than diesel. DPG20 showed 2.72% lower value than P20. Hence, better combustion efficiency was observed for G20 and DPG20 than P20, which ultimately resulted better performance and emission characteristics. Higher flash point ensures safety of fuel for handling, storage and prevention from unexpected ignition during combustion. G20, P20 and DPG20 showed higher flash point about 20.1%, 13.1% and 30.22%, respectively than diesel. Comparing to P20, DPG20 showed about 15.28% increased flash point. In case of the calorific value, P20 and DPG20 exhibited lower values about 2.34% and 1.31%, respectively, than diesel, whereas, G20 showed about 1.27% higher values than diesel. The higher calorific value of any fuel is desired because it favours the heat release during combustion and improves engine performance. CN is a measure of a fuel's auto-ignition quality characteristics. DPG20, P20 and G20 showed higher CN approximately 18.37%, 10.2% and 26.53%, respectively when compared to diesel. DPG20 showed about 7.28% higher CN than P20.

3.2. CO emission

Fig. 2a illustrates the variation of the CO emission values of diesel, G20, P20 and DPG20. It had been observed that all of the blends showed lower CO emission than diesel and G20 showed greater emission reduction compared to all of those. On average, DPG20, P20 and G20 showed decreased CO emission approximately 23.47%, 19.21% and 25.96%, respectively, when compared to the reference fuel diesel. When compared to P20, DPG20 showed about 5.53% lower CO emission. The higher CN of G20 induces shortening of ignition delay that prevents less over-lean zones [6]. Besides, the lower distillation temperature of GTL fuel induces rapid vaporization, which reduces the probability of flame quenching and thus ensures lower CO emission [7]. In case of the other two blends, lower CO emissions can be explained by the combined effect of the high oxygen content and higher CN [8]. In case of DPG20, the combined presence of GTL fuel and PBD resulted more reduction of CO emission than diesel and P20.

3.3. HC emission

Fig. 2b illustrates the variation of the HC emission values of diesel, G20, P20 and DPG20. It had been observed that all fuels showed lower HC emission values than diesel. Overall, G20 showed greater emission reduction compared to all fuels. On average, DPG20, P20 and G20 showed decreased HC emission approximately 23.62%, 15.74% and 27.49%, respectively, when compared to the reference fuel diesel. When compared to P20, DPG20 showed about 9.35% lower HC emission. Alike CO emission, the reduction of HC emission for all of the sample fuels can be explained by the same happenings.

3.4. NO_x emission

Fig. 3a illustrates the variation of the emission values of diesel, G20, P20 and DPG20. It had been observed that P20 and DPG20 blends demonstrated higher NO_x emission, whereas G20 showed lower NO_x emission values, when compared to diesel. Overall, G20 showed the lowest NO_x emission compared to all other sample fuels. On average, DPG20 and P20 showed increased NO_x emission values about 1.63% and 3.51%, respectively, when compared to diesel. In comparison to P20, DPG20 showed about 1.87% lower NO_x emission. In case of G20, test results revealed approximately 9.06% decreased values than diesel. The higher CN of G20 induced shorter ignition delay, followed by a lesser premixed charge, which resulted the lower combustion temperature and pressure [6, 9]. It leads towards less thermal NO_x formation. In case of the other two blends, higher NO_x was observed because of their high oxygen content and a higher "premixed part" during combustion, where NO_x is primarily formed [7, 8]. For DPG20, the presence of GTL fuel in this combined blend resulted additional reduction of NO_x content in exhaust emission than P20.

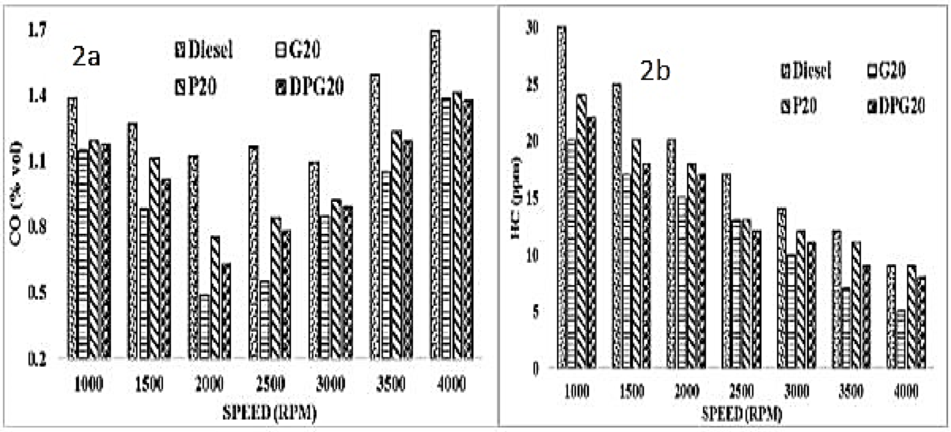

Fig. 2: Variation of CO (2a) and HC (2b) emission of all test fuels.

3.5. Smoke emission

Fig. 3b illustrates the variation of the smoke emission values of diesel, G20, P20 and DPG20. It had been observed that the diesel-biodiesel blends and G20 showed lower smoke emission values than diesel. Overall, G20 showed greater emission reduction compared to all sample blends and diesel. On average, DPG20, P20 and G20 showed decreased smoke emission approximately 18.89%, 15.28% and 19.18%, respectively, when compared to the reference fuel diesel. When compared to P20, DPG20 showed about 4.26%, 5.65%lower smoke emission. This reduction in smoke emissions in G20, which is in accordance with that observed in the literature, can be illustrated by the combined effect of the absence of aromatics (regarded as soot predecessors), low sulphur content and higher hydrogen to carbon ratio of GTL fuel [6, 10]. Regarding the reduction of the other two blends, the higher oxygen content associated with lower sulphur content and impurities can be attributed to such diminution of smoke emission [7], [8]. For DPG20, the incorporation of GTL fuel and PBD with diesel, demonstrated additional reduction of smoke emission than diesel and P20.

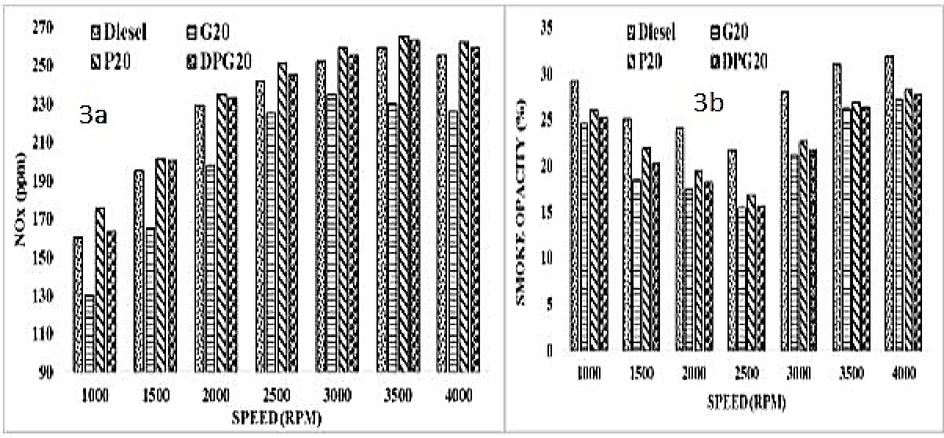

Fig. 3: Variation of NO_x (3a) and smoke (3b) emission of all test fuels.

4. Conclusion

In this study, three blends of P20, G20 and DPG20 were used for a comparative investigation in terms of the fuel properties and engine exhaust emission than diesel. Exhaust emission experiments revealed significant reduction for G20 than the other fuels. On average, G20 showed reduction in CO, HC, NO_x and smoke emission approximately 25.96%, 27.49%, 9.06% and 19.18%, respectively, compared to diesel. On average, P20 and DPG20 demonstrated higher NO_x about 3.51% and 1.63%, whereas lower values of CO about 19.21% and 23.47%; HC about 15.74% and 23.62%; smoke about 15.28% and 18.89%, respectively than those of diesel. Moreover, DPG20 showed an average reduction in CO, HC, NO_x and smoke emissions about 5.53%, 9.35%, 1.87% and 4.26%, respectively than those of P20. Among all the test blends G20 and DPG20 showed promising improvement in exhaust emissions compared to the all fuels.

5. Acknowledgement

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