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EFFECT OF NANO-MATERIAL ON THE PERFORMANCE PATTERNS OF WASTE COOKING BIODIESEL FUELLED DIESEL ENGINE

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Abstract

This work paves a way on improving the Lower efficiency and higher consumption of biodiesel on a diesel engine. Biodiesel fuelled engine emits lower emission with inferior performance. Hence this work examines the effect of adding nano-material (novel graphene oxide, GO) on biodiesel derived from waste cooking oil on engine its performance. Waste cooking oil is transesterified into waste cooking oil biodiesel (WCBD) by using alcohol (Methanol), catalysts (KOH). GO nano-material is dispersed into WCBD at 100 and 200 ppm and termed as WCBD100GO and WCBD200GO respectively. Performance experiments were conducted on a diesel engine using WCBD, WCBD100GO and WCBD200GO at the same conditions. Experimental results show that the WCBD100GO and WCBD200GO have lesser BSFC (0.3 and 0.7 kg/kWh), EGT (07 -16°C) and higher BTE (0.4-1.2 %) than WCBD. The improvement in the performance aspects are of WCBD is owing to the Oxygen content and catalytic activity of GO nano-materials.

Keywords: Waste cooking oil; Transesterification; Oxygen content; Catalytic activity.

1. Introduction

Biodiesel (BD) is a potential alternative to diesel because of availability and renewable nature [1-3]. BD has comparable properties to diesel. BD is manufactured by numerous methods that are crushing, pyrolysis, transesterification. In which, transesterification is widely acknowledged and most dependence method for producing BD [4, 5]. The results gathered from BD studies are showed higher BSFC and lower BTE than diesel. There is a strict reduction in engine power ignition characteristics [6-11]. Recently, adding nano-material to BD is widely followed to enhance its usage. Nano-material enhances the heat transfer between fuel and air and aids combustion. Much work involved by adding nano-material to BD/ diesel blends. They conformed drastic enhancement in BTE (0.2-1.4%) with lower fuel consumption. Yuvarajan et al., [12] added 50-100 ppm of CeO_2 nano-material to BD/diesel blends. ZnO lowered the viscosity of BD/diesel blends and improved BTE by 0.4%. Also, the fuel consumption lowered by 1.1 % for 100 ppm CeO_2 added BD/diesel blends. Balan et al., [13] added 10-20 ppm of ZnO nano-material to BD/diesel blends. ZnO enhanced the flash, pour and fire point of BD/diesel blends and improved BTE by 0.6%. Further, the fuel consumption lowered by 1.4% for 20 ppm ZnO added BD/diesel blends. Sudaliamuthu et al. [14] added 100-200 ppm of CNT nano-material to BD/diesel/alcohol blends. CNT enhanced the flash, pour and fire point of BD/diesel blends and improved BTE by 0.9%. Further, the fuel consumption lowered by 1.2% for 20o ppm ZnO added BD/diesel blends. Many works proved that nano-material doped fuels reduced the fuel consumption of about 1-2.5% with significant improvement in the properties. Devarajan et al., [15] added 50-100 ppm of TiO_2 nano-material to BD/diesel blends. TiO_2 enhanced the mass diffusivity of BD/diesel blends and improved BTE by 0.7%. Further, the fuel consumption lowered by 2 % for 100 ppm TiO_2 added BD/diesel blends. The outcome from various literature replicates that there is a limited study available on usage of graphene oxide nano-material on the performance pattern of a diesel engine fueled with neat WCBD. Performance aspects such as thermal efficiency exhaust gas temperature and fuel consumptions are detailed using the base and modified fuels (WCBD, WCBD100GO and WCBD 200GO) in a single-cylinder diesel engine.

2. Materials and methods

2.1. BIODIESEL

Biodiesel is produced by conventional transesterification which requires used cooking oil, alcohol (Methanol), catalysts (KOH). The oil and alcohol are mixed at certain acceptable molar ratio (6:1) along with the catalysts at 1.3%wt and heated to a temperature of 70°C. The mixture is then vigorously stirred for homogenous mixing for a time interval (60 minutes). After heating; this mixture is allowed to settle. This process results in the splitting of two products (Waste cooking biodiesel and glycerol). The by-product (Glycerol) is removed from an ester by gravity-based separation. The obtained ester is washed, dried and termed as WCBD. GO nano-material is dispersed into WCBD at 100 and 200 ppm and termed as WCBD100GO and WCBD200GO respectively. TEM and SEM image of GO included WCBD is shown in figure 1. The properties of WCBD, WCBD100GO and WCBD200GO were calculated by ASTM. Table 1 shows the properties of WCBD, WCBD100GO and WCBD 200GO.

Table 1. Properties of WCBD, WCBD100GO and WCBD 200GO

Figure 1. TEM and SEM image of GO nano-particle dispersed in WCBD

2.2. Experimental setup

This work used an air-cooled, four-stroke, single-cylinder engine. The schematic of the engine is shown in figure 2. The rated power of the equipped engine is 4.5 kW. 17.5.1 is the compression ratio maintained during the trial. The stroke length and a bore diameter of the engine are 110 and 87.5 mm respectively. 1800 rpm constant speed was maintained during the study. The complete specification of the engine is listed in Table 2.

Figure 2. The layout of the engine

Table 2. Specification of Experimental Setup

2.3 Testing conditions

The diesel engine was initially fuelled with diesel fuel and made to run for 20 minutes to maintain the steady-state condition. Further, the diesel in the engine fuel injection pump is replaced by neat WCBD and made to run for 45 minutes at ambient condition. This ensured the complete replacement of diesel and

CBD. Then the performance characteristics such as BTE, EGT and BSFC were measured by changing the load of the engine from 0 to 100% load. Similarly, the WCBD was replaced by WCBD100GO and WCBD 200GO.

2.4. Uncertainty analysis

In view of uncertainties, the preferred test results can be examined of any work [15-18]. If a quantity to be measured "R" has a function of many self-regulating variables like

$x_1, x_2, x_3, \ldots x_n$, then $R = R(x_1, x_2, x_3, \ldots x_n)$

The mean-square-root procedure is used to observe the uncertainty proportion of measured performances. $\text{Overall uncertainity} = \sqrt{(\mathrm{BTE}^2 + \mathrm{BSFC}^2 + \mathrm{EGT}^2)}$ (1)

The uncertainty (Overall) is 1.5%.

3. Results and discussion

3.1. BSFC

BSFC for WCBD, WCBD100GO and WCBD200GO with load are shown in figure 3. BSFC for WCBD, WCBD100GO and WCBD200GO are lower with a load. WCBD, WCBD100GO and WCBD200GO produce higher BSFC than diesel. WCBD produce 0.51 kg/kWh BSFC at part load, whereas WCBD100GO and WCBD200GO produce 0.48 and 0.44 kg/kWh BSFC at part load. At part load, WCBD100GO and WCBD200GO produce 0.3 and 0.7 kg/kWh lower BSFC to WCBD. WCBD produce 0.32 kg/kWh BSFC at full load, whereas WCBD100GO and WCBD200GO produce 0.29 and 0.27 kg/kWh at full load. At full load, WCBD100GO and WCBD200GO produce 0.3 and 0.5 kg/kWh lower BSFC to WCBD. GO nano-particles present in WCBD100GO and WCBD200GO increase the density of air-fuel charge as a result of enhanced fuels heat evaporation rate and lower BSFC [30]. The improved properties of WCBD100GO and WCBD200GO enhance the atomization and combustion process and lower BSFC than WCBD. Further, the supplementary oxygen content in WCBD100GO and WCBD200GO yields improved combustion efficiency and lower BSFC. WCBD100GO and WCBD200GO generate better atomization throughout the combustion process, lower latent heat of vaporization, higher flame temperature and lower BSFC [31]. This results arrived concur with many studies of similar work [32-34].

Figure 3. Variation in BSFC with load

3.2. EGT

EGT for WCBD, WCBD100GO and WCBD200GO with load are shown in figure 4. EGT amplify with the load. WCBD, WCBD100GO and WCBD200GO produce higher EGT than diesel. WCBD produce 162°EGT at part load, whereas WCBD100GO and WCBD200GO produce 155 and 146°at part load. At part load, WCBD100GO and WCBD200GO produce 7 and 16°lower EGT to WCBD. WCBD produce 369° EGT at full load, whereas WCBD100GO and WCBD200GO produce 362 and 356°at full load. At full load, WCBD100GO and WCBD200GO produce 7and 13 °lower EGT to WCBD. GO nano-particles present in WCBD100GO and WCBD200GO enhance the fuel and air entrainment which lead to complete combustion and lower EGT [25]. Further, GO nano-particles present in WCBD100GO and WCBD200GO and improve the properties of WCBD and provide the required activation energy for during combustion which lessens EGT. Adding GO nano-particles in WCBD100GO and WCBD200GO enhance and accelerate the combustion reaction between air-fuel owing to its improved oxygen content [26]. Fuel with higher oxygen content burn freely and completely and results in lower EGT. This results arrived concur with many studies of similar work [27-29]

Figure 4. Variation in EGT with load

3.3. BTE

BTE for WCBD, WCBD100GO and WCBD200GO with load are shown in figure 5. BTE WCBD, WCBD100GO and WCBD200GO amplify with the load. WCBD, WCBD100GO and WCBD200GO produce low BTE than diesel. WCBD produce 5.9% BTE at part load, whereas WCBD100GO and WCBD200GO produce 6.4 and 7.1 % at part load. At part load, WCBD100GO and WCBD200GO produce 0.5 and 1.2 % higher BTE to WCBD. WCBD produce 27.2% BTE at full load, whereas WCBD100GO and WCBD200GO produce 27.6 and 28.1% at full load. At full load, WCBD100GO and

WCBD200GO produce 0.4 and 0.9 % higher BTE to WCBD. GO nano-particles present in WCBD100GO and WCBD200GO foils the deposition of iron and carbon which lowers the friction and enhance the BTE [19]. Further, adding GO nano-particles accelerates the reaction between fuel and air at the micro-level. This micro-level acceleration lowers the viscosity of WCBD100GO and WCBD200GO [20]. Fuel with lower viscosity enhances the mixing of WCBD100GO and WCBD200GO with air and roots higher BTE [21]. This results arrived concur with many studies of similar work [22-24].

Figure 5. Variation in BTEwith load

4. Conclusion

This work investigates the effect of doping novel graphene oxide nano-material (GO) on Waste cooking Biodiesel (WCBD) and views its effect on engine performance. The Major findings from this study are outlined below

- Better atomization throughout the combustion process, lower latent heat of vaporization, the higher flame temperature of GO nano-particles lowers the BSFC of WCBD100GO and WCBD200GO by 0.3 and 0.5 kg/kWh than WCBD at full load.
- WCBD100GO and WCBD200GO produce 7and 13 ° lower EGT to WCBD at full load. GO nano-particles enhance the fuel and air entrainment which leads to complete combustion and lower EGT.
- GO nano-particles foils the deposition of iron and carbon which lowers the friction and enhance the BTE. BTE for WCBD100GO and WCBD200GO is increased by 0.4 and 0.9 % than WCBD at full load.

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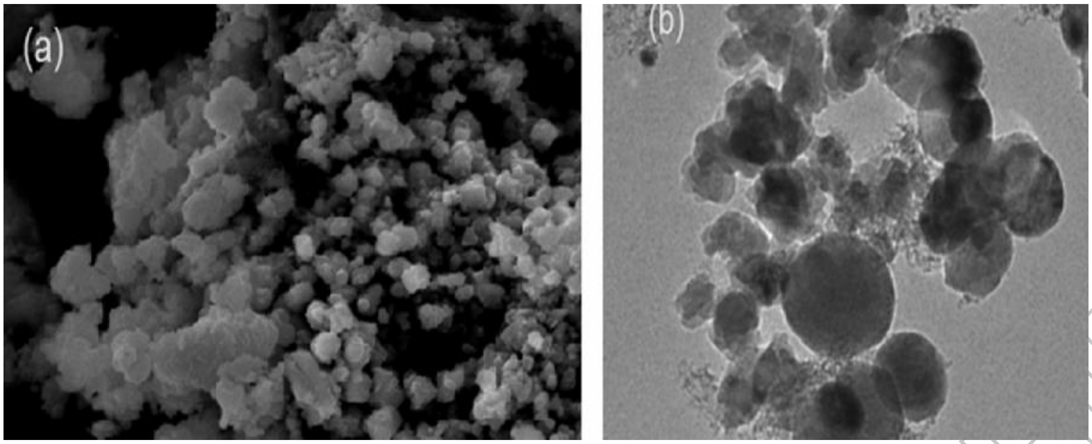

Figure 1. TEM and SEM image of GO nano-particle dispersed in WCBD

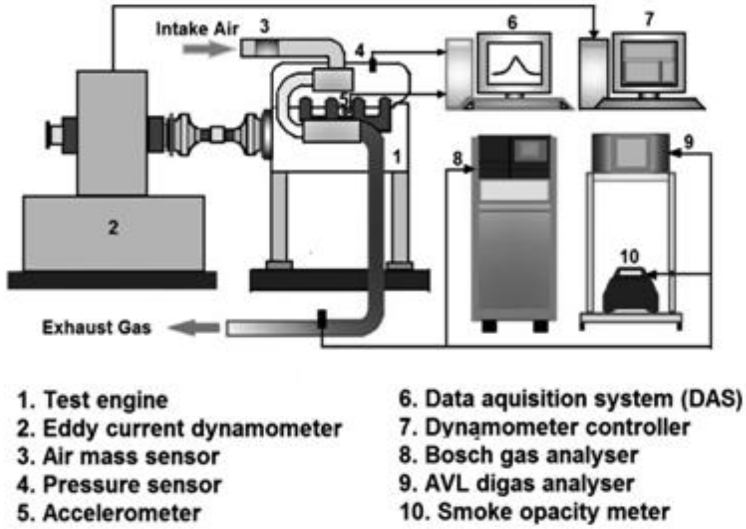

Figure 2. Layout of the engine

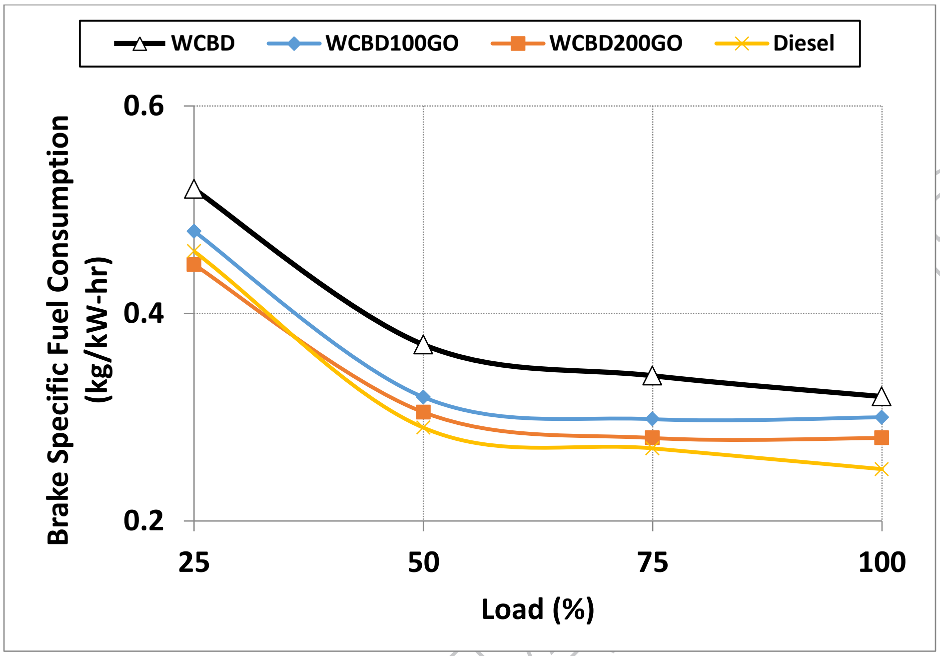

Figure 3. Variation in BSFC with load

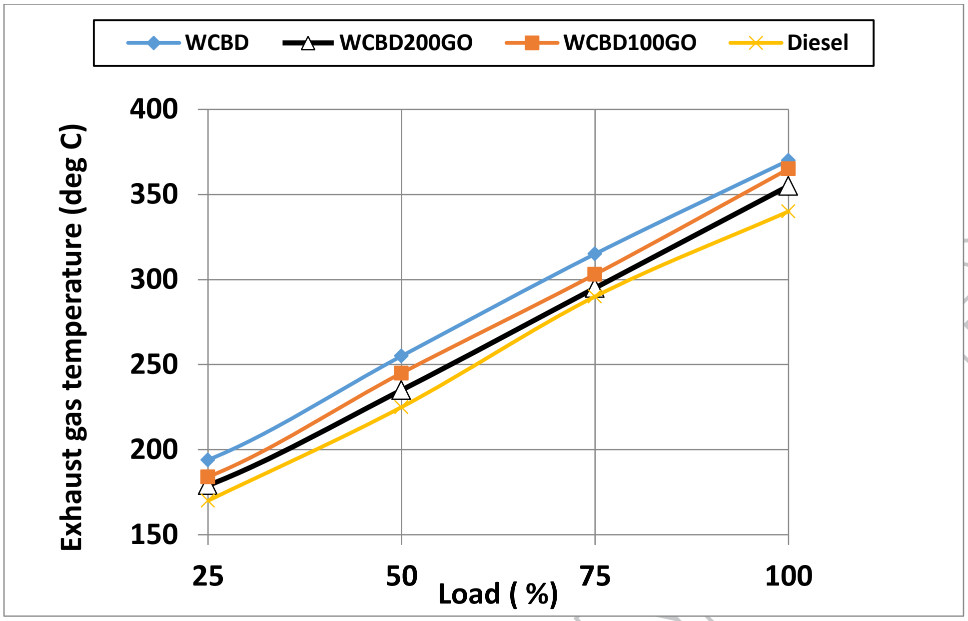

Figure 4. Variation in EGT with load

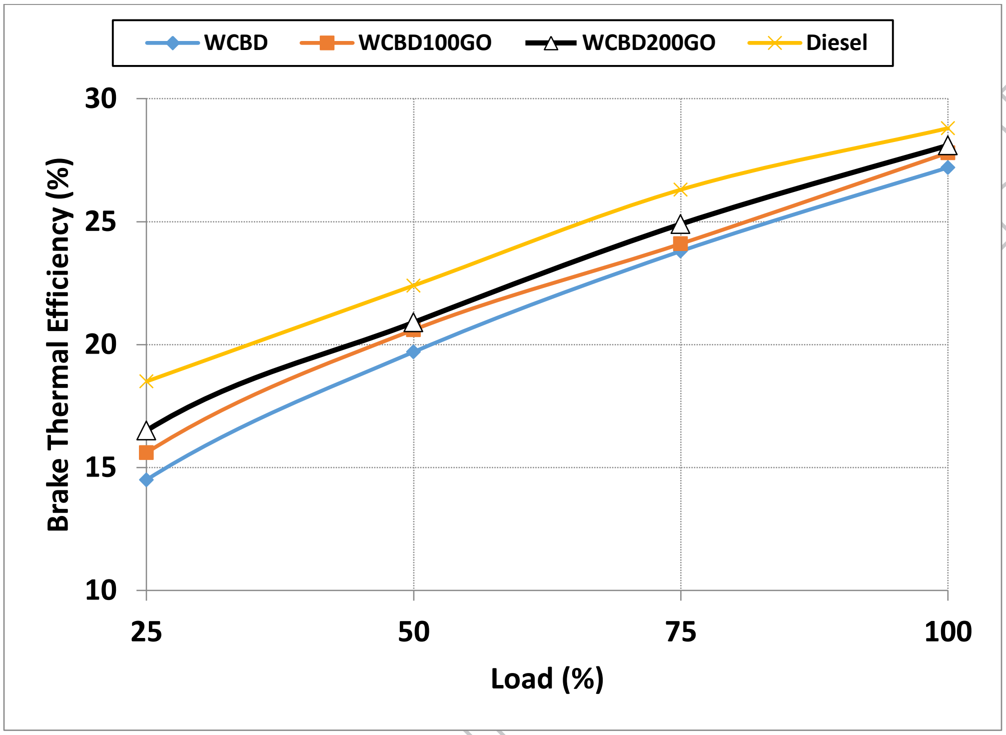

Figure 5. Variation in BTE with load

Table 1. Properties of WCBD , WCBD100GO and WCBD 200GO

PROPERTIES	WCBD	WCBD100GO	WCBD200GO
Density @ 15°C (gm/cc)	0.75	0.73	0.72
Kinematic Viscosity @40°C (mm^2/s)	4.5	4.4	4.3
Calorific Value (kJ/kg)	38250	38512	38740
Flash point (°C)	144	148	152
Cetane Index (CI)	65	69	74
Fire point (°C)	151	158	162

Table 2. Specification of Experimental Setup

Make	Kirloskar
Stroke	4
Cylinder	Single
Rated power	4.5 kW
Rated speed	1800 rpm
Bore diameter (D)	87.5 mm
Stroke (L)	110 mm
Compression ratio	17.5:1
Injection Timing	21°bTDC