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Brake torque of a diesel engine fuelled with biodiesel and diesel

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Abstract: Brake torque of a diesel engine was investigated by considering the effects of biodiesel (from waste cooking oil) in fuel mixture (biodiesel and diesel fuel) on this performance characteristic. The experiments were done on a 4 cylinder direct-injection diesel engine. Results showed that by the use of biodiesel brake power decreases up to17%. Also results showed that the increase in engine load appeared to cause an increase in the brake power up to 69%. On the other hand by increasing rpm of the engine brake power increases continuously up to speed 1800 to 2000 rpm and after that drops.

Keywords: Brake Torque, Biodiesel, Diesel, Engine

1. Introduction

As a renewable, sustainable and alternative fuel for compression ignition engines, biodiesel instead of diesel has been increasingly fueled to study its effects on engine performances and emissions in the recent 10 years.

The resources of petroleum as fuel are dwindling day by day and increasing demand of fuels, as well as increasingly stringent regulations, pose a challenge to science and technology.

With the commercialization of bio energy, it has provided an effective way to fight against the problem of petroleum scarce and the influence on environment.

Bio fuels such as alcohols and biodiesel have been proposed as alternatives for diesel engines (Agarwal, 2007; Demirbas, 2007; Ribeiro et al., 2007). The fuel properties of biodiesel may be changed when different feedstocks are used. If the fuel properties of biodiesel are compared to petroleum diesel fuel, it can be seen that biodiesel has higher viscosity, density, pour point, flash point and cetane number, near-zero aromatic compound, and no sulphur link (Canakci and Ozsezen, 2005; Knothe, 1997).

In particular, biodiesel has received wide attention as a replacement for diesel fuel because it is biodegradable, nontoxic and can significantly reduce toxic emissions and overall life cycle emission of CO_2 from the engine when burned as a fuel (Cvengroš and Považanec, 1996; USEPA, 2002). Biodiesel can form blends with petroleum diesel fuel at any ratio and thus have the potential to partially, or even totally, replace diesel fuel in diesel engines.

Biodiesel fuel has many effects on diesel engine performance. There has been a lot of research on the regulated performance characteristics of diesel engines with biodiesel/diesel blends.

Biodiesel can be produced from various vegetable oils, waste cooking oils and animal fats. The fuel properties of biodiesel may be changed when different feedstocks are used. If the fuel properties of biodiesel are compared to petroleum diesel fuel, it can be seen that biodiesel has higher viscosity, density, pour point, flash point and cetane number, near-zero aromatic compound, and no sulphur link (Canakci and Ozsezen, 2005; Knothe, 1997).

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There are many literatures to study the effect of pure biodiesel on engine torque, and most of them agreed that, with biodiesel (especially with pure biodiesel), engine torque will drop (Utlua and Kocak, 2008; Aydin and Bayindir, 2010; Hazar, 2009; Ozsezen et al., 2009; Karabektas, 2009; Xue et al., 2011; Keskin et al., 2008). However, the results reported show some fluctuation. Utlu and Kocak (2008) found that the respective average decrease of torque values of WFOME (waste frying oil methyl ester) was 4.3% and 4.5%. Hansen et al. (2006) observed that the brake torque loss was 9.1% for B100 biodiesel relative to D2 diesel at 1900rpm.

Murillo et al. (2007) found that the loss of torque was 7.14% for biodiesel compared to diesel on a 3-cylinder, naturally aspirated (NA), submarine diesel engine at full load. Yücesu and Cumali (2006) found that the torque and power reduced by 3–6% for pure cotton seeds biodiesel compared to diesel.

It was reported that there was no significant difference in engine torque and power between pure biodiesel and diesel (Lin et al., 2009; Qi et al., 2009). For instance, Lin et al.(2009) found that the maximum and minimum differences in engine torque and power at full load between PD (petroleum diesel) and 8 kinds of VOME (vegetable oil methyl ester) fuels were only 1.49% and −0.64%, 1.39% and −1.25%, respectively. And Qi et al. (2009) reported this trend.

Of course, it was reported that there were surprising increases in torque of engine for pure biodiesel (Song and Zhang, 2008; Al-Widyan et al., 2002). Song and Zhang (2008) observed that the engine brake torque increased with the increase in biodiesel percentage in the blends. But it is the most unbelievable that the increased torque of the pure biodiesel could reach 70% relative to diesel fuel (Al-Widyan et al., 2002).

Although the basic trends of engine torque performance with load or speed were similar for biodiesel engine and diesel engine, there existed offset of maximum value of torque for biodiesel compared to diesel (Aydin and Bayindir, 2010; Gumus and Kasifoglu, 2010).

Hossain et al. (2012) investigated full engine power with both blends, and very little difference in engine performance results were observed between 20% and 30% blends. At full engine load, the brake specific fuel consumption on a volume basis was around 6% higher for the blends when compared to fossil diesel.

The brakes thermal efficiencies were about 3–6% lower than biodiesel and were similar to fossil diesel. The study concludes that up to 20% blend of de-inking sludge pyrolysis oil with biodiesel can be used in an indirect injection CI engine without adding any ignition additives or surfactants.

Palm fatty acid distillate that is a waste from extraction of palm oil. PFAD is used by Malvade et al. (2013) for production of biodiesel. A single cylinder water cooled diesel engine was used for evaluating performance of PFAD biodiesel blends and diesel.

The engine performance for various PFAD biodiesel blends at various loads was comparatively equal to that of diesel fuel. Brake power of various blends is comparatively equal to brake power of diesel. Brake Thermal Efficiency increases comparatively for 50% PFAD blends. Specific Fuel Consumption for PFAD blends is slightly higher than diesel. Indicated power of PFAD blends is less than indicated power of diesel.

The biodiesel diesel blends (10%, 20%, 30% and 50%) were used by Silitonga et al. (2013) to conduct engine performance and exhaust emission characteristic at different engine speeds. The experimental results showed that CPB10 blend give the best results on engine performance such as engine torque and power at 1900 rpm with full throttle condition. Besides, the brake specific fuel consumption at maximum torque (161 g/kW h) for CPB10 is higher about 22.98% relative to diesel fuel (198 g/kW h). This is shown that the lower biodiesel diesel blends ratio will increase the performance and reduce the fuel consumption.

Koc et al. (2013) investigated the effects of water concentration in a biodiesel nanoemulsion fuel on engine performance and exhaust emissions of a diesel engine. Biodiesel nanoemulsions containing 5%, 10% and 15% water were used for the engine tests and the results were compared with B5, B20 and certified diesel fuels.

Biodiesel nanoemulsion with 5% water concentration produced engine power and torque values that were similar to the values measured for B5 fuel.

Emulsified biodiesel fuel is a promising alternative method for reducing harmful emissions from diesel engines without requiring significant engine modifications.

Yamin et al. (2013) presented a comparative study on the use of new as well as waste oil as source for biodiesel fuel for compression ignition engine. The engine performance and emission characteristics were studied and compared with pure diesel fuel.

The results showed that there was a loss in the fuel calorific value of about 13.43% for waste oil biodiesel and 7.24% for unused oil biodiesel. Further, the density of the fuel was found to increase by about 4.75% with respect to pure reference fuel. As for the performance, biodiesel showed improvement in the torque, power and thermal efficiency and reduction in the specific fuel consumption. This was achieved both as full and low load.

Liaquat et al. (2013) investigated the engine performance parameters and emissions characteristics for direct injection diesel engine using coconut biodiesel blends without any engine modifications.

A total of three fuel samples, such as DF (100% diesel fuel), CB5 (5% coconut biodiesel and 95% DF), and CB15 (15% CB and 85% DF) respectively are used. Engine performance test has been carried out at 100% load, keeping throttle 100% wide open with variable speeds of 1500 to 2400 rpm at an interval of 100 rpm.

As results of investigations, there has been a decrease in torque and brake power, while increase in specific fuel consumption has been observed for biodiesel blended fuels over the entire speed range compared to net diesel fuel.

Effect of Karanja biodiesel (Karanja oil methyl ester; KOME) and its blends on engine performance, emissions and combustion characteristics in a direct injection compression ignition (DICI) engine of a medium size utility vehicle with varying engine speed and load has been investigated by Dhar et al. (2014). Maximum torque attained by 10% and 20% KOME blends were higher than mineral diesel, while higher biodiesel blends produced slightly lower torque.

Özener et al. (2014) studied the combustion, performance and emission characteristics of conventional diesel fuel and biodiesel produced from soybean oil and its blends (B10, B20, B50) were compared. The tests were performed at steady-state conditions in a single-cylinder direct injection diesel engine over the entire rpm range (1200–3000 rpm). During the tests, the fuel consumption, pollutant emissions, exhaust temperature and in-cylinder pressures were measured.

The experimental results, showed that, relative to diesel, biodiesel had a 1–4% decrease in the torque and an approximately 2–9% increase in the brake-specific fuel consumption (BSFC) due to the lower heating value (LHV) of the biodiesel

The objective of this research work is to investigate the effects of biodiesel percentage of in fuel mixture (biodiesel and diesel fuel No.2) as fuel parameter and engine speed and engine load as engine operation parameters on changes in brake torque of a diesel engine. In addition, using diagrams, the interaction effects of process parameters on the parameters are analyzed and discussed.

2. Materials and Methods

2.1. Biodiesel Preparation and Fuel Properties

Biodiesel from waste vegetable cooking oil is a more economical source of the fuel, so biodiesel was produced from this source in the present investigation. In the present research, biodiesel was produced by transesterification process TMU biofuels laboratories. The important properties of biodiesel and No. 2 diesel are shown in Table 1.

Table 1. *Properties of diesel and biodiesel fuels used for present investigation*

Property	Method	Units	Biodiesel	Diesel
Flash point	ASTM-D92	°C	150	61
Pour point	ASTM-D97	°C	-5	0
Cloud point	ASTM-D2500	°C	-1	3
Kinematical viscosity, 40°C	ASTM-D445	mm2/s	4.3	4.15
Density	---------	Kg/m3	875	830

2.2. Test Engine Experimental Setup and Procedure

The engine tests were carried out on a 4-cylinder, four-stroke, turbocharged, water cooled and naturally aspirated DI diesel engine. The engine speed was measured by a digital tachometer with a resolution of 1 rpm. The engine was allowed to run for a few times until the exhaust gas temperature, the cooling water temperature, the lubricating oil temperature, have attained steady-state values and then the data were recorded.

3. Analysis and Results

Brake torque

Figures (1 to 4) show the effects of biodiesel percentage and engine speed on the brake torque of the engine at various load condition. As the Figures show the maximum brake torque is more than 334 N.m for fuel blends included less than 15% biodiesel at full load and engine speed between 1700 to 1900 rpm. Also the minimum brake torque (15 N.m) happens at 25% engine load and 1000 rpm as engine speed for fuel blends included more than 80% biodiesel.

The values for the brake torques decrease slightly with the increasing amount of biodiesel in the fuel blend. These decreases are understandable, since the heat content of the fuel blend decreases with the increasing amount of biodiesel compared to that diesel fuel No.2 (Aydin and Bayindir, 2010; Hazar, 2009; Ozsezen et al., 2009; Karabektas, 2009; Hansen et al., 2006; Kim and Choi, 2010; Canakci et al., 2009). High lubricity and the higher oxygen content of biodiesel might result in the reduced friction loss and thus improve the brake effective torque and compensates the loss of heating value of biodiesel (Ramadhas et al., 2005).

Figures (1 to 4) show the brake torque increases with increasing engine load, because the increase in combustion temperature leads to more complete combustion during the higher load (Xue et al., 2011).

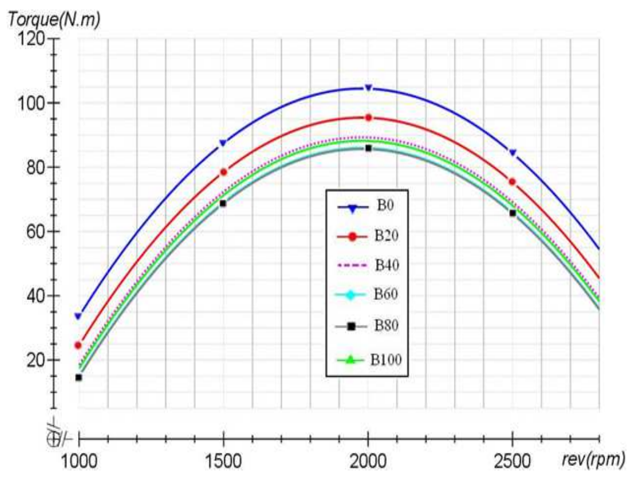

Fig 1. *Effect of Percentage of biodiesel in fuel mixture and engine speed on brake torque at 25% engine load.*

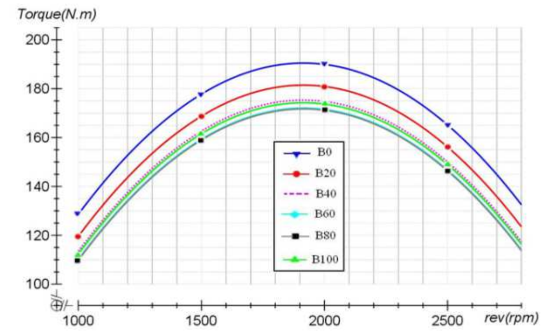

Fig 2. *Effect of Percentage of biodiesel in fuel mixture and engine speed on brake torque at 50% engine load.*

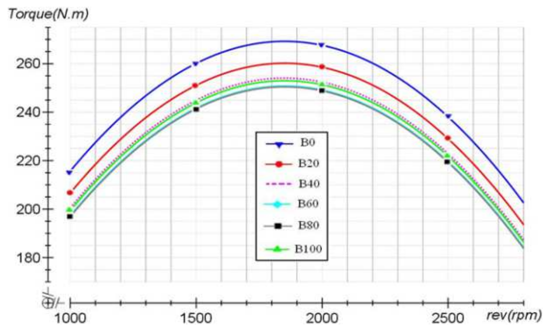

Fig 3. *Effect of Percentage of biodiesel in fuel mixture and engine speed on brake torque at 75% engine load.*

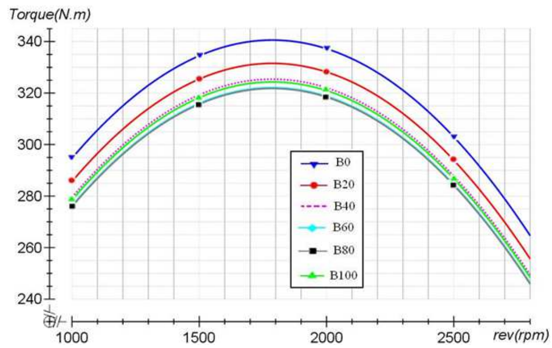

Fig 4. *Effect of Percentage of biodiesel in fuel mixture and engine speed on brake torque at full engine load.*

4. Conclusions

The brake torque decreases with the increase of biodiesel in the blends, due to the lower heating value of biodiesel. Results showed that the brake torque of diesel No.2 fuel is more than 5% and 17% more than the brake torque of net biodiesel at full and 25% engine load respectively.

The increase in engine load appeared to cause an increase in the brake torque up to 68%.

These results are similar to those found in the literature and support that waste cooking oil methyl esters have similar properties with diesel fuel.

By increasing rpm of the engine brake torque increases continuously up to speed 1800 to 2000 rpm and after that drops.

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