Performance Evaluation of Locally-Produced Waste Cooking Oil Biodiesel with Conventional Diesel Fuel

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***Abstract*—Increasing environmental concerns forced us to look for cheaper, reliable and secure sources of energy. Fossil fuels like oil, coal, and natural gas are having limited supplies and are depleting fast. Both energy security and environmental concerns have resulted in inclination towards renewable energy sources. Biodiesel does not contain petroleum, but it can be blended with petro-diesel in various mix levels. This research investigated biodiesel produced by the use of cheap waste cooking oil, collected from the local market of Nawabshah, Pakistan. The collected waste oil was converted into biodiesel by trans-esterification process at PCSIR Laboratory, Karachi. The fuel samples were tested in a diesel engine test bed unit at the Thermodynamics Laboratory of Quaid-e-Awam University. Biodiesel blends were compared with the conventional diesel fuel. The comparative analysis of the performance parameters concluded that brake specific fuel consumption of B30 (biodiesel 30%+diesel 70%) mix was 6.9% higher than that of 100% diesel. The brake thermal efficiency of B30 decreased about 4.75% in comparison with conventional diesel.**

Keywords-biodiesel; WCO; BSFC; BTE; engine

I. INTRODUCTION

Biodiesel can be produced with the use of waste cooking oil (WCO) as raw material. Four types of WCO, sunflower, maize, olive and palm can be used for the production of biodiesel [1]. Global petroleum production is decreased while the current reserves are limited [2]. B100 is generally known as fresh fiery alternate fuel and can be produced from domestic and renewable resources. It comprises no petroleum and can be blended by any ratio level with petroleum diesel to produce biodiesel blends. Biodiesel is produced by the use of methanol and ethanol with alkali catalyst. Biodiesel blends can be used with conventional diesel with or without any major modification. WCO biodiesel has less ignition delay. The blend of 20% WCO biodiesel + 80% diesel has good brake thermal efficiency and indicates slightly more specific fuel consumption [3]. It is used as an environmentally friendly fuel. It has decreased greenhouse gas emissions and particulate matter emissions and other air toxics. Biodiesel reduces premature exhausting of fuel pumps and recovers lubricity [4].

II. RELATED STUDIES

WCO biodiesel is renewable, biodegradable and nontoxic. Physical parameters like methyl ester fatty acids which are produced by the esterification process are similar to those of diesel. Blended biodiesel can be used in engines directly without any modification. Other feed stocks have also been used in the synthesis of biodiesel [5-7]. The EU prefers raw materials such as rapeseed oil, sunflower oil and cotton-seed oil [8, 9]. The production of biodiesel from waste vegetable oil is cheaper than from other feed stocks. The benefits of using WCO to produce biodiesel are its low cost and the decreased emitted greenhouse gasses [10]. The density of WCO is about 10% greater and the kinematic viscosity of WCO is 10 times greater than that of conventional diesel. Some modifications are compulsory in the engine when WCO is used in engines [9, 11]. If the free fatty acids (FFAs) of WCO oil are greater than 2% then it needs esterification process before trans-esterifcation [12].

III. EXPERIMENTAL SETUP

WCO was collected from two different chicken frying shops in Nawabshah. It was converted in biodiesel by trans-esterification on PCSIR Laboratory at Karachi, by the algorithm shown in Figure 1.

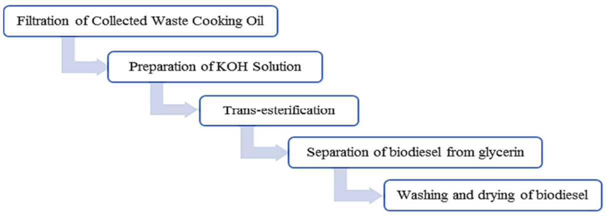

Fig. 1. Algorithm for bio-diesel production

Filter/cotton cloth filtered the collected WCO. The oil to methanol ratio was 1:8. 183ml of methanol were put in a beaker of 250ml, along with 13.5g of dissolved KOH. 500g of WCO were taken in a glass flask connected with a reflux condenser using tap water to condense methanol vapour. The mixture was agitated by the use of a magnetic stirrer, and heated to 55^0C-60^0C. When oil temperature increased to 55^0C-60^0C, the prepared KOH solution was poured into the oil with stirring at 150rpm. After one hour, the mixture was poured into a separating funnel. Glycerol, additional methanol and unused products were in the lower layer and were separated. The upper layer of biodiesel (ester) was washed several times with warm water (40^0C) until the washing was neutral. The final product (biodiesel) was then dried over anhydrous sodium sulphate and filtered.

IV. PERFORMANCE EVALUATION

Diesel performance evaluation was carried out in the Thermodynamics Laboratory of the Quaid-e-Awam University of Engineering, Science and Technology Nawabshah, Sindh, Pakistan. The engine model was DWE-6/10-JS-DV. The specification details of the engine are illustrated in Table I.

TABLE I. DIESEL TEST ENGINE SPECIFICATIONS

Number of cylinders	1
Cooling system	Water cooled
Type	Horizontal
Piston size (bore)	80mm
Displacement of piston (strokes)	95mm (477cc)
Compression ratio	23:1
Starting method	Manual
Output/rotational speed	8.5PS/2200 rpm(max)

Two fuel tanks were attached to the diesel engine test bed. One common pipeline was used for supplying fuel to the engine. Both fuel tanks were linked with the common line. The flow could be controlled by two separate valves as shown in Figure 2. The first tank was filled with diesel fuel (D100), and the second one with the test selected fuel. Under this study, three selected fuels were tested: Diesel (D100), 20% biodiesel+80% diesel (B20) and 30% biodiesel+70% diesel (B30). Their specifics are given in Table III. Exhaust gas temperature (EGT), brake specific fuel consumption (BSFC) and brake thermal efficiency (BTE) were measured at constant engine speed and variable load ranged from 0kg to 2.0kg at 1300rpm.

TABLE II. FUEL COMPOSITION BY VOLUME

D100	Pure Diesel
B100	100% Biodiesel
B20	20% biodiesel+80% diesel
B30	30% biodiesel +70% diesel

TABLE III. COMPARATIVE PHYSICAL PROPERTIES OF OIL SAMPLES

Physical Property	Unit	D100	B20	B30	ASTM standard	Testing limits
Total Acid Number	mgKOH/g	0.24	0.27	0.28	D-664	0.80 max
Specific gravity*	-	0.83	0.85	0.84	D-891	0.8-0.9
Kinematic Viscosity**	mm^2/s	1.98	2.78	2.43	D-445	1.9-6.0
Density**	g/cm^3	0.85	0.86	0.86	D-1298	0.86–0.90
Cetane index (Calculated)	-	56.9	54.4	53.5	D-976	47 min
Flash point	^{0}C	103	123	115	D-93	130 min
Pour Point	^{0}C	0	+1.5	+1.8	D-97	-15 to +5
Calorific value	MJ/kg	44.8	43.2	43.8	D-240	37.5-45

* at 15.6^{0}C
** at 40°C

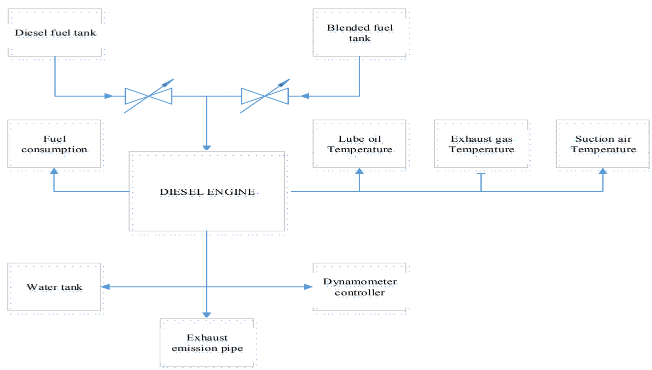

Fig. 2. Experimental setup of diesel engine

Fig. 3. D100 and biodiesel specimens

V. RESULTS AND DISCUSSION

Performance analysis was determined on a single cylinder diesel engine. A dynamometer was directly joined to the engine and could control the varying load. A dynamometer controller was connected to the panel. A water tank for cooling, and two fuel tanks were attached to the diesel engine test bed. One common pipeline has been used to supply the fuel. Three different fuel types were experimented with. The performance parameters were determined on varying load at 1300rpm. The load range was 0N.m-2N.m. In this comparative study, the performance parameters were EGT, BSFC and BTE with varying brake power (BP).

A. Exhaust Gas Temperature (EGT)

EGT increases continuously with load increase. During high engine load considerable heat was rejected. Biodiesel and its blends have decreased percentage of heat rejected by the cooling fluid due to their lower combustion temperature. The smaller burning gas temperature is responsible for biodiesels' quick combustion for the period of premixed combustion. It was observed that at increasing brake load the engine using D100 exhausted more temperature than when using B20 and B30, whereas B30 had reduced exhaust temperature than B20. The comparative results of EGT are shown in Figure 4.

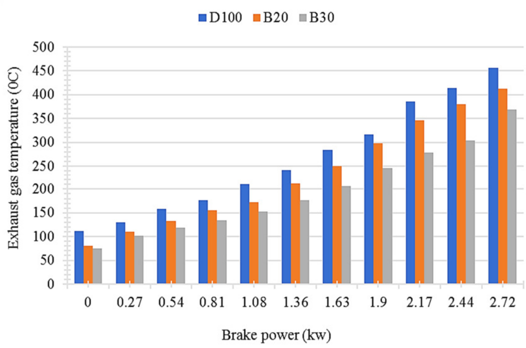

Fig. 4. Comparative results of EGT with BP

B. Brake Specific Fuel Consumption (BSFC)

Biodiesel showed higher BSFC than diesel for each different brake power of the engine because biodiesel and its blends have lower density and calorific value. The SPFC has been expressed by kg/kWh. BSFC increases at high loads having improved fuel smoke related with the high fuel-air mixture in the compression-ignition (CI) engine. At low loads BSFC increases due to decreased mechanical efficiency. It is observed that brake fuel consumption is increased with increase in the blending ratio of biodiesel due to biodiesel's low viscosity and density. Consequently, the BSFC of B30 was higher than the ones of D100 and B20. The BSFC of B30 was 6.9% higher than that of D100 and 2.9% than that of B20. The detailed of comparative results of BSFC are shown in Figure 5.

C. Brake Thermal Efficiency (BTE)

The BTE decreased when the blending ratio increased. The compression ratios of the blended biodiesel were compared with pure diesel D100. The air-fuel ratio and volumetric efficiency decreased with increase in the concentration of biodiesel in the fuel [13-15]. It was observed that vegetable oil blends with methanol and ethanol provide lower thermal efficiency than diesel fuel. The BTE of diesel is higher than that of biodiesel fuel due its higher viscosity, lower heating value, poor spray quality and higher volatility [16, 17]. Increase in blending percentage of biodiesel in the diesel fuel improves its combustion process due to biodiesel's higher oxygen content. The average value of BTE of B30 is decreased by 4.75% when compared to D100. The comparative results of BTE are shown in Figure 6.

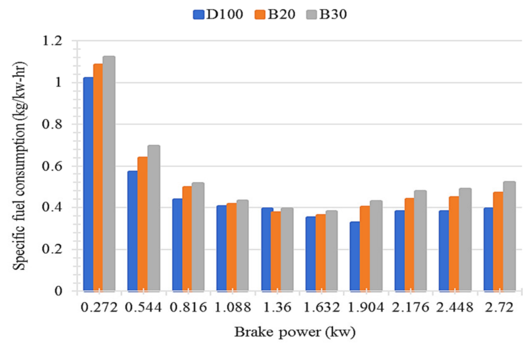

Fig. 5. Comparative results of BSFC with BP

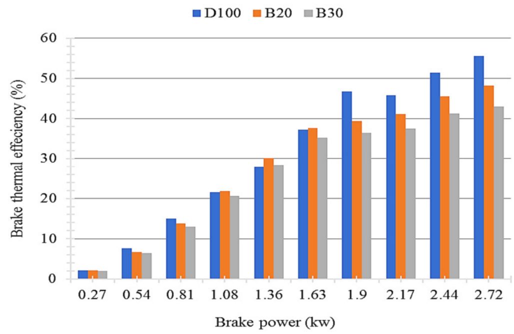

Fig. 6. Comparative results of BTE with BP

VI. CONCLUSION

This research and experimental work consisted in engine performance analysis. Three fuels, D100, B20 and B30 were tested without any modification of the diesel engine. Based on the obtained results, B30 showed reduced exhaust gas temperature due to its quick combustion and improved fuel characteristics. The BSFC of B30 was 6.9% higher than the one of D100 due to its higher combustion and large oxygen content. BTE was lower for biodiesel as compared to D100. When the blending percentage of biodiesel in the diesel fuel increased, the average value of BTE of B30 decreases 4.75% as compared to D100.

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