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Research Article

Study on the Performance and Exhaust Emission of a Diesel Engine Fueled with Waste Cooking Oil and Its Blends

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Abstract

Biodiesel in any form, whether in pure state or in a mix with other components such as diesel fuel is extensively examined to answer some specific questions that are identical in the process of exhaustion of hydrocarbon in the earth (fossil fuels) which really have effect on the environment that is causing climate change and other environmental dreadful conditions. Waste vegetable cooking oil (WCO) which is a by-product of restaurant after the daily activities and collected as the residue of the vegetable oils. This oil has high possibility to use as a mix fuels for operating diesel engines for supply of energy for its optimal performance. The most important intention of the current research is to evaluate the execution of combustion of the oil, its effluents and burning characteristics of biodiesel fuel resulting from using the blend of waste cooking oil mix with normal fuel (diesel) at B10% and B20% (that is 10% of waste cooking oil mix with 90% diesel) base and the volume is then preheated for the fuels to ignite. The evaluation structures that assess the performances which were: brake pedal thermal effectiveness, brake pedal precise energy utilization, energy productivity. The emission structure includes carbon monoxide, carbon dioxide, un-burnt hydrocarbon (shoot), oxides of nitrogen and smoke opacity. These are then measured with diverse fuels mix and weigh against the base line outcome. The diverse characteristics of waste cooking oil subsequent to transesterification were contained by satisfactory boundaries of standards as stipulated by various nations. The brake pedal thermal effectiveness of waste cooking oil methyl ester and its mix with diesel were inferior to diesel and brake pedal precise energy utilization was discovered to be superior. Nevertheless, carbon monoxide, carbon dioxide, hydrocarbons and smolder were discovered to be lower with waste cooking oil biodiesel fuel. NOx emissions on waste cooking oil biodiesel and its mixture were higher than Diesel. The outcome from the research propose that biodiesel resulting from waste cooking may possibly be a superior alternate to diesel fuel in diesel engine in the nearest future and its mixture may perhaps be utilized in a traditional diesel engine devoid of any alteration.

Keywords: *Waste cooking oil, Brake thermal efficiency, Exhaust emissions*

1. Introduction

With the present energy situation, key important survey is paying attention to sustainable energy solution with main prominence on the use of energy effectively and the use of renewable energy sources. Diesel engines have demonstrated that they have higher potential in the transportation and power sectors because of its ability to produce higher effective consumption and ruggedness in its performance. Waste cooking oil biodiesel and its mixture with Diesel are prospective foundation of decentralized energy production for diminutive electrification generation plant (Kalam and Masjuki 2004) in addition to uninterrupted augment in manufacturing of vehicles by innovative and former automobile industries in the current time boast by the understanding to show the way to a soaring requirement for gasoline manufactured items, researchers have argued that the global availability of natural gas and petroleum product from conventional supplies does not have the capacity to meet the needed growing energy demand for the next two decades going by the present need worldwide (Bhupendra *et al*, 2012). There is also growing concern about the depletion of the natural gas and petroleum product because of it been a non-renewable energy.

In the last twenty years, vegetable oil is increasingly been utilized as an replacement for diesel fuel in an internal-combustion engine (Bhupendra *et al*, 2012), (Muralidharan and Vasudevan, 2011) ,(Taymaz and Sengil 2010) , example include mahua oil, sunflower oil, seed oil, waste cooking oil ,palm oil and so on and so forth. A range of scholars have investigated many researches to evaluate the performance and emission distinctiveness of diesel engine when vegetable oils, that is a mixture of vegetable oil and its offshoots are developed as an alternate to fossil fuel in an internal-

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combustion engine with or without engine alteration that mostly relied on alternative-fuel type, nonetheless, the scholars have discovered that the biodiesel fuel is financially viable and competitive when measure up with the conventional diesel or fossils fuel (An H, *et al*, 2012), (Ballesteros, et al, 2010), (Murugesan, *et al* , 2009). On the other hand, apprehensions about long-term availability of petroleum diesel due to it been a non-renewable resources and the harsh environmental standards have authorized the exploration for a renewable substitute to diesel fuel so as to solve these problems associated with the use of petroleum diesel or fossil fuel (Belyamin, *et al,* 2013) .

Furthermore, biodiesel gotten from the mix of waste vegetable oil and diesel have inferior sulphur and aromatics contents (hydrocarbons), superior lubricity and viscosity, enhanced biodegradability and lower toxicity and reduced net carbon dioxide (CO_2)emission in comparison to fossil diesel (Masjuki , et al, 1996) .The most important advantages of the used cooking oil to create a center of attention among the admired scholars are the renewable and greener qualities it possess that is not harmful to the environment. This advantage was as a result of interrelated properties with the diesel fuel. Utilized cooking oil can be acknowledged as an appropriate alternate to the diesel fuel because it is a derivative from plants, vegetable oils and animal fats which are renewable and it is from biomass sources. Although biodiesel cannot completely substitute petroleum-based fuels, bio-fuels and diesel fuel mixed can be utilized on present engines to accomplish both environmental harmony and sustainable energy efficiency.

Bio diesel can be utilized more effortlessly because it can be blended at any ratio with diesel oil, therefore, it enable us to apply it straight away for diesel engines that are obtainable within us exclusive of much alteration, it is also easily biodegradability, it is 10 times less harmful to human health when contrast with normal diesel oil, it has an improved cetane number compared with the common diesel, however there are some shortcomings in the process of using WCO with fuel in engine as an alternative to pure diesel oil only, it has higher viscosity that makes the fuel to have difficulty to flow or transmit to engine, it is density also make it o be incompletely combusted and therefore clog the fuel filter, Waste Cooking Oil because of its thickness requires preheating which is essential to steer clear of this trouble by lessen the fuel viscosity. (Sureshkumar and Ganesan 2008). Testifies that though the utilization of biodiesel has an advantage of lower emissions of un-burnt hydrocarbons, carbon monoxide, smoke and particulate matters, on the other hand it has higher increase in emissions of Nitrogen compounds (NOx).

Despite the fact that it has a higher viscosity because of the colossal molecular mass and chemical structure of vegetable oils, it restricts its straight forward usage in diesel engines, which in turn consequence on the transmission troubles and disproportionate load on the fuel pumps, waste cooking vegetable oil obtained from restaurant was trans esterified and most important physicochemical properties were appraised in agreement with ASTM standards. Additionally, a density explosion engine was fuelled with Waste cooking methyl ester and it was mix together with diesel. Its performance, burning and emissions distinctiveness were assessed to discover its appropriateness as a diesel engine fuel. The research considers the properties of all the emission, combustion and performance characteristics of the waste vegetable cooking oil. The results obtained were contrasted with those from the diesel fuel to make necessary justifications.

2. Experimental setup

2.1 fuel setup

Waste cooking oil was obtained from restaurants and hotels for this experiment; these are the hotels and restaurants that are using pure vegetable oil for cooking. The waste oil sample was obtained from the kitchen that uses the vegetable oil for frying eggplant, potatoes; chicken pieces among others. Furthermore, oil from vegetables based food items was also collected. Seven litters of oil was collected as sample and was obtained from the reservoir that act as a collecting drum that the waste cooking oil normally kept as a waste once in 10 hours . Potassium Hydroxide (KOH) was utilized as catalyst in this particular experiment. The quantity of catalyst used has effect on the conversion of esters during the Transesterification procedure. The oil sample was heated up in a beaker to a temperature of 110^{o}C to evaporate the water from it. The oil was filtered using a cloth to separate any particles. In order to determine the amount of catalyst is required for Transesterification, titration was carried out using a concentrated KOH standard solution because Potassium Hydroxide absorb the excess oxygen and form water that is evaporated by the heating of the oil to a higher temperature. A 500 ml glass beaker was used as the reactor; this beaker was then placed in a heating plate with stirrer for mixing. There was total separation of the glycerin Biodiesel and impurities as residues in the oil; this was achieved after 24 hours by gravity method.

2.2 Engine setup

The Engine used for this research was a four cylinder, four strokes, liquid cooling DI – Diesel engine type 3Y made in Japan coupled with mechanical dynamometers. The most important engine distinctiveness is shown in Table 1and Figure 1.

The materials for the experiment were obtained from different sources, while the conventional diesel fuel was obtained from the South Iraq Petroleum Corporation (SIPC), waste cooking oil was obtained by purchasing it from local restaurant and mixed with the

SIPC diesel in the ratio of 10% and 20% based on volumetric standardization. The properties of fuels used in this research was scrutinized at the Najaf refinery laboratory and shown in Table 2.

Table 1 Engine test specification

Type 3Y made in japan	4 stroke, vertical cylinder diesel engine
Compression ratio	20:1
Bore x stroke	78 x 67mm
Displacement	2.7L
Combustion system	Direct injection
Cooling system	liquid
Maximum engine speed	3600(rpm)
Starting system	Electric start/Recoil start
Max Rated output(KW) @3600rpm	4.9

Fig.1 The engine coupling with dynameters used in this experimental

Table 2 Fuel test properties

Specification	Pure diesel	B10	B20
Specific gravity @60f⁰	0.8448	0.8448	0.8453
Density @15c⁰kg/m³	844.3	844.3	844.8
A p I	36.0	36.0	35.9
Viscosity 28c⁰	7.123	6.897	6.893
Viscosity 40c⁰	5.17	5.131	5.063
Viscosity 100c⁰	1.781	1.671	1.667
Viscosity index	243.35	250.57	263.73
Pour point c⁰	3	3	3
Flash point c⁰	84.0	83	86
gross calorific value(kJ/kg)	45652.0	45801.3	45201.4

3. Result and Discussion

3.1 Brake specific fuel consumption (BSFC)

The contrasting of Brake Specific Fuel Consumption (BSFC) with engine loads of different fuel mixtures for a different engine speeds are shown in Figure 2. Analysis from this Figure indicated that observation of BSFC is an apparent indication of the effectiveness with which engine develops power from BSFC. Also the analysis of all the fuels experimented; the BSFC was increasing with increase the mixture percentages compare to diesel. At higher percentage of mixture, the BSFC indicated increase in its performance; this is due to the decrease in calorific value for the higher mixes. From Figure 3.1 it has been observed that the maximum BSFC reduction for B10 is by 0.65% at fuel temperature 85C⁰ than room temperature. This because the B10 fuel type has high caloric value compare and less viscosity in this degree to other fuels stated in Table 2.

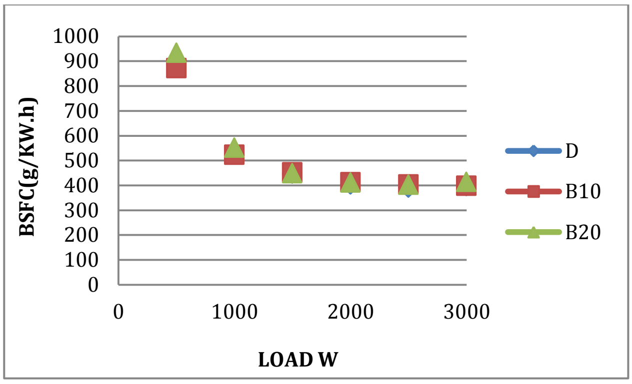

Fig.2 Variation of brake specific fuel consumption with engine load for different fuel blends

3.2 Brake Thermal Efficiency, ($B\eta_{th}$)

Figure 3. indicated the variation in $B\eta_{th}$ with engine load for a mixed fuel tested. The $B\eta_{th}$ was discovered to be lesser for biodiesel at all the experimented mixture compared with diesel fuel for all load. This may be because of lesser fuel heat value and elevated fuel utilization by the biodiesel mixture to generate same energy .The proportion of net energy generated by the engine and the speed of heat supplied from combustion of fuel. It indicated that the proportion of heat energy that is converted to work. The brake thermal efficiency of the engine looked at one of the most important criteria for evaluating the performance of the engine.

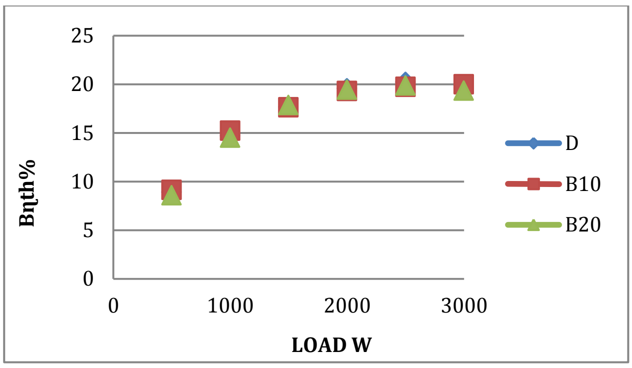

Fig.3 Variation of thermal efficiency with engine load for different fuel blends

3.3 Exhaust Gas Emission

3.3.1 Carbon monoxide emission (CO)

Figure 4. shows the variations of Carbon Monoxide (CO) emissions for different fuel mixture in respect to engine load at diverse engine rate. From the Figure, it can be seen that the CO emission of the particular mixture was little less than or equal to the CO emission for diesel engine for almost all the rates, nevertheless there is variation in the proportion. CO concentration of the engine with the biodiesel and diesel mixture diminishes with the augmentation of O2 mass fraction in the mixture. This is also for the reason that the combustion promotion from O2 fortification. Also the proportion of CO reduces owing to increasing temperature in the combustion compartment; physical and chemical properties of the fuel, air–fuel ratio, and the consequences of fuel thickness on fuel spray superiority would be anticipated to create some CO swell with vegetable oil fuels (Canakci and Van Gerpen, 2003) in this case discovered that preheated fuel at 85C0 temperature is required to lessen the thickness.

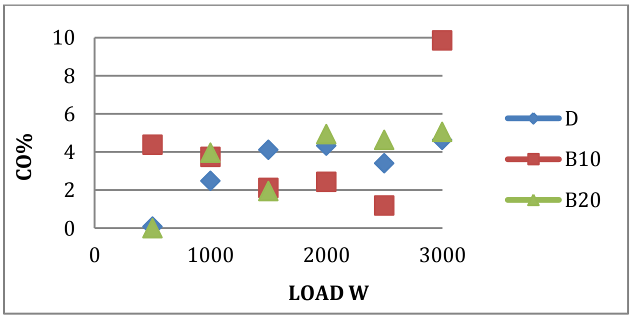

Fig.4 Variation of brake specific fuel consumption with engine load for different fuel blends

3.3.2 Carbon dioxide emission (CO2)

The contrasting of Carbon Dioxide emission with engine load is indicated in Figure 5.

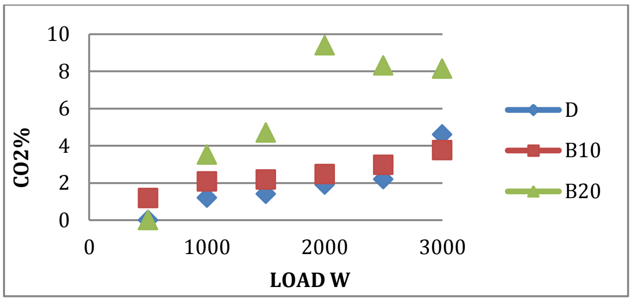

Fig.5 Variation of brake specific fuel consumption with engine load for different fuel blends

Analysis from the Figure shows that the Carbon Dioxide emission CO2 amplifies when there is increase the fuel proportion. CO2 emission of the fuel mixture is slightly boosted by an increase in the load for particular engine rate owing to absolute combustion and adequate involvement of oxygen. Mixture of bio-fuel and petroleum diesel increase CO2 by8.5% and 12%for the B10 and B20 respectively then diesel this due to high oxygen content of blends (Shurvell, et al, 1995).

3.3.3 Nitrogen oxides (NOx) emission

The deviation of NOx emissions according to engine load for various mixtures with diversity engine rates was shown in Figure 6. As seen in this Figure, the NOx emission for diesel and mixed waste vegetable cooking oil was increased with the increased of engine loads. The augment in the biodiesel ratio in the fuel blend increased NOx emissions by 1.26% and 1.38% for B10 and B20, respectively, the reason for higher NOx emission for blends is owing to higher peak temperature (Shurvel, et el 1997).

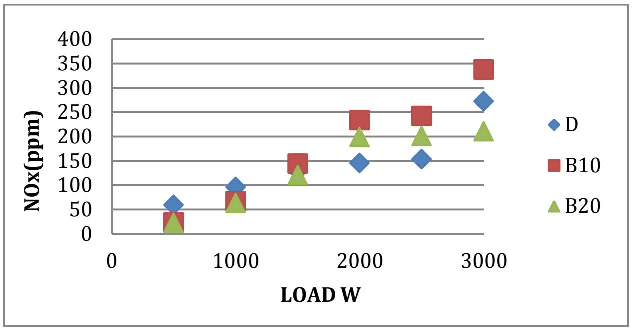

Fig.6 Variation of brake specific fuel consumption with engine load for different fuel blends

Conclusions

An experimental investigation was conducted on four cylinder direct injection diesel engine liquid cooling system to appraise and evaluate the performance, combustion and exhaust emission at different blends and loads. The conclusions are summarized as follows:

1) Bη_{th} of the blends increases with increase the load. The maximum η_{th} at full load is 22.55% for B10, which is 3.7% higher than that of diesel.
2) BSFC of the engine gradually decreases with increased fuel temperature. BSFC of the blends B10 at full load is 598.499 g/kWh, whereas for Diesel it is 599.95 g/KW.h at 85C^0
3) The NOx emission for the blends is higher than that of diesel except B10 at applied loads.
4) The CO decrease by 4.2% and 0.5% when increase the blends percentage for B10 and B20 respectively
5) Blends fuel increase CO_2 by8% and 11%for the B10 and B20 respectively than diesel.
6) From the above results, it has been found that the performance of the B10 blend is superior when compared with the conventional. For fuelling the engine with biodiesel.

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