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Experimental Comparison of Combustion Characteristic and Pollutant Emission of Gas oil and Biodiesel

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***Abstract*—**The increasing industrialization and motorization of the world has led to a steep rise for the demand of petroleum-based fuels. Petroleum-based fuels are obtained from limited reserves. These finite reserves are highly concentrated in certain regions of the world. Therefore, those countries not having these resources are facing energy/foreign exchange crisis, mainly due to the import of crude petroleum. Hence, it is necessary to look for alternative fuels which can be produced from resources available locally within the country such as alcohol, biodiesel, vegetable oils etc. Biodiesel is a renewable, domestically produced fuel that has been shown to reduce particulate, hydrocarbon, and carbon monoxide emissions from combustion. In the present study an experimental investigation on emission characteristic of a liquid burner system operating on several percentage of biodiesel and gas oil is carried out. Samples of exhaust gas are analysed with Testo 350 Xl. The results show that biodiesel can lower some pollutant such as CO, CO_2 and particulate matter emissions while NO_x emission would increase in comparison with gas oil. The results indicate there may be benefits to using biodiesel in industrial processes.

***Keywords*—**biodiesel, combustion, gas oil, pollutant

I. Introduction

THE increasing focus on the environmental impacts of fossil fuel based power generation has led to increased research with the aim of reducing emissions and improving combustion efficiency. Much of this work is driven by the increasing interest into alternative fuels such as biodiesel, bioalcohol, chemically stored electricity, hydrogen, non-fossil methane, non-fossil natural gas, oil, and other biomass sources. The use of biodiesel is rapidly expanding around the world, making it imperative to fully understand the impacts of biodiesel combustion process and pollutant formation. Biodiesel fuel is defined as mono alkyl esters of long-chain fatty acids derived from renewable lipid feed stocks, such as vegetable oils or animal fats, for use in diesel engines and liquid burners.[1] The definition excludes pure vegetable oils and mono- and di-glycerides which cannot be considered as biodiesel. Furthermore, the fact that biodiesel must be produced from renewable fats eliminates any confusion with other substances to which this name has been attributed in the past [2]. Various oils have been in use in different countries as raw materials for biodiesel production owing to its availability. Soybean oil is commonly used in United States and rapeseed oil is used in many European countries for biodiesel production, whereas, coconut oil and palm oils are used in Malaysia for biodiesel production [1–4]. Transesterification of edible oils has also been carried out from the oil of canola and sunflower. Other edible and non-edible oils, animal fats, algae and waste cooking oils have also been investigated by researchers for the development of biodiesel [5-11]. Type and amount of variables such as feedstock, alcohol, molar ratio, catalyst, reaction temperature, time duration, rate and mode of stirring affects the yield and conversion of biodiesel. Biodiesel can lower some pollutant and particulate matter emissions. It can be blended with diesel fuel in any proportion and be used in conventional diesel engine without any major modification. Slightly higher viscosity of biodiesel makes it an excellent lubricity additive. [6] Biodiesel is nontoxic and biodegradable when introduced in neat form [7], and it is an oxygenated fuel which contributes to a more complete fuel burn. Its cetane number is higher than those of vegetable oil and diesel fuel [8] and hence produce less THC emission [9, 10]. Biodiesel does not contain any aromatic components, and with low sulfur content produces low exhaust PM emissions, sulfur dioxide and lower aromatic HC emissions [10, 11, 12]. Many researches have been developed on biodiesel and its characteristics. The behavior of biodiesel in internal combustion engines is well documented in the literature [12-22]. Engine performance is slightly lower when using biodiesel because of its lower heating value with respect to that of diesel fuel; if the injection phase is done well, engine efficiency doesn't significantly change. Reduction in regulated emissions has been reported as well: pure biodiesel shows an average reduction of 50% for CO, 65% for total unburned hydrocarbons (HC), 50% for particulate matter (PM). NOx emissions, on the contrary, are 10% higher; for biodiesel–diesel blends' reductions vary

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almost proportionally with the concentration of biodiesel in the blend. The most promising blend is the mixture of 20% biodiesel 80% diesel fuel, commonly known as B20 blend. Biodiesel has also showed interesting results when used in boilers for space heating [23-27]. These studies have shown that boiler efficiency doesn't change significantly whereas the specific consumption increases due to the lower heating values of biodiesel. A significant decrease in CO, HC and SO2 emissions with respect to home heating oil has been observed. NOx emissions, on the contrary, show both reduction [19-22] and increase [26, 27]. Win Lee et al. [26], investigating the combustion performance of B20 blend in a residential-scale hot water boiler, reported a 20% reduction in SO2 and 13% reduction for PM; NOx and CO emissions were similar or slightly higher with biodiesel to that of the reference heating oil. They also point out an increase in CO emissions during the starting sequence of the boiler and with very low external temperatures. The aim of this paper is measuring regulated emissions such as CO, CO_2 , NO_x and flame temperature from boiler fueled with biodiesel and liquid fuel for comparison.

II. Experimental Setup

The laboratory furnace which is used in this research includes a horizontal cylinder to the length of 170 cm and diameter of 50 cm. On the rims of furnace some orifices in different spaces from burner nozzle have been made for measuring temperature and sampling combustion gases. The schematic design of laboratory system has been shown in figure1. Figure 2 demonstrate the experimental combustion chamber.

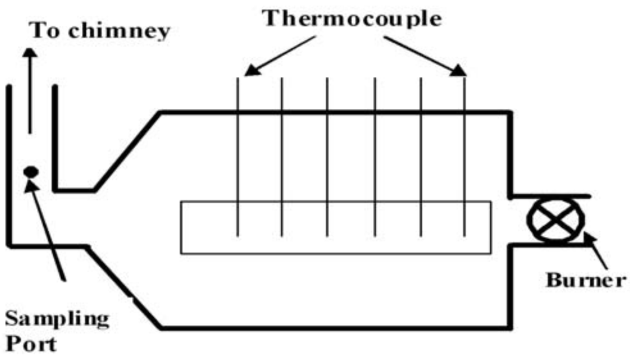

Fig. 1. Schematic of liquid fuel laboratory Combustion chamber

In order to avoid heat transfer and controlling the temperature of furnace body, it is covered with glass wool 1260(which stands temperature, up to 1260c) and thickness of 50mm. The burner of furnace has 2MW maximum power of with 2.5 MPa pressure of input fuel to nozzle. The rate of fuel stream and input air to the combustion chamber by fuel pump and burner vent is adjustable.

Fig. 2. Laboratory combustion chamber

Specification of burner under experiment has been presented in tables I. Table II demonstrates the properties of Biodiesel and gas oil which are used as fuel.

TABLE I
FEATURES OF BURNER

Power source [V]	AC 220V/50Hz,60Hz
Motor [W]	110
Oil pump[kcal/kg]	Gear pump
Pump pressure [Mpa]	2.5
Nozzle range [gal/h]	1.25
Spray angle [degree]	60

TABLE II
PROPERTIES OF GAS OIL AND BIODIESEL

Properties	Unit	Standard (ASTM)	Gas Oil (B0)	B20	B40
Density	g/ cm^3	D4052	0.815	0.849	0.861
Viscosity	Cst	D445	2.45	3.01	3.29
Low Heating Value	MJ/kg	D240	42.5	41.2	39.6
Cetane Number	-	D613	57.3	59.6	60.6
Flammability point	◦C	D93	61	72	94
C	[%]	D6548	85.05	86.66	88.27
H_2			14.9	14.42	13.94
O_2			0	2.1	4.2
S_2			0.05	0.04	0.03

All of the measurements are made after stabilization of furnace temperature, because changing the temperature of fuel cause changes in the concentration and viscosity of fuel and these factors effects on the size of fuel drops .during the experiments, the air and input fuel temperature has been controlled and maintained. A sampling device has been placed for analyzing gas in the stack, on the 160cm from furnace vent. The gas stream produced from combustion like CO, CO_2 and NO_x is registered each 5 minutes using a Testo 350 XL for analyzing gas.

III. Results and Discussion

Experimental study on combustion characteristic of biodiesel and gas oil is investigated. The results indicate an enhancement in feature of combustion and pollutant emission with use of biodiesel instead of gas oil. Fig. 3. presents the effect of equivalence ratio on exhaust gas temperature. The figure shows that the temperature of exhaust gas has increased slowly with increase of equivalence ratio for gas oil and biodiesel fuels. The maximum temperature occurs at φ=1.3 for gas oil but when using biodiesel that happens at φ=1.15. It can be seen that the temperature increases when using biodiesel with higher percentage.

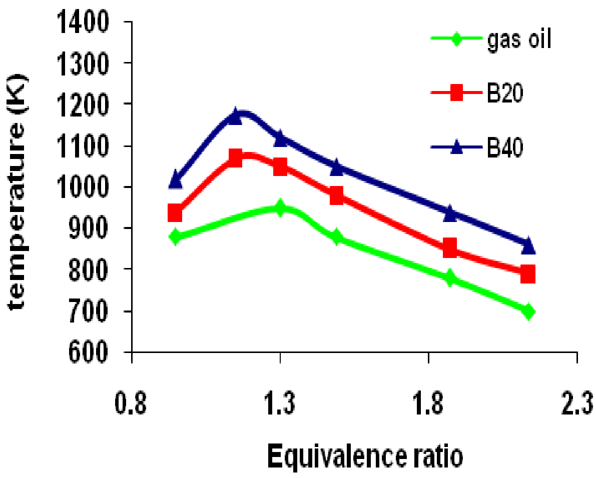

Fig.3 –Effect of equivalence ratio on temperature for burner fueled with biodiesel and gas oil

Figure 4 shows the effect of equivalence ratio on NO_x formation. A slight increase in the case of biodiesel can be noticed. It can be seen that NO_x formation with both gas oil and biodiesel increases as the equivalence ratio increase. But maximum rate of NO_x formation occurs at φ=1.4 and for biodiesel fuel at φ=1.5. Following formulas are used to calculate CO percentage of mole fraction.

Theoretical CO_2 % by volume = (moles of CO_2/Total moles)×100 (1)

$$\%\ \text{Excess air} = \left(\frac{\text{Theoritica l } CO_2\%}{\text{Actual } CO_2} - 1\right) \times 100 \qquad (2)$$

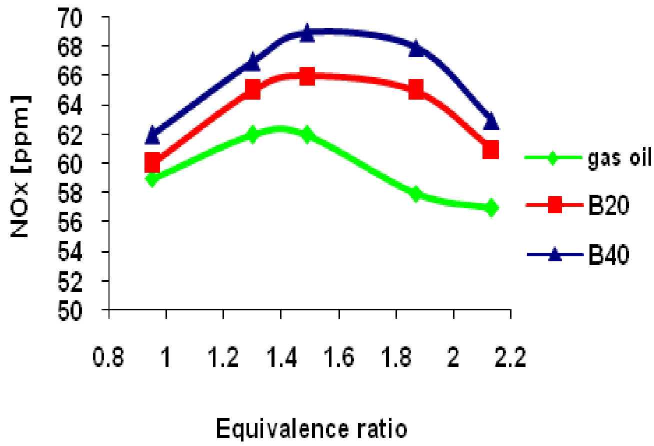

Fig.4 –Effect of equivalence ratio on NO_x emission for burner fueled with biodiesel and gas oil

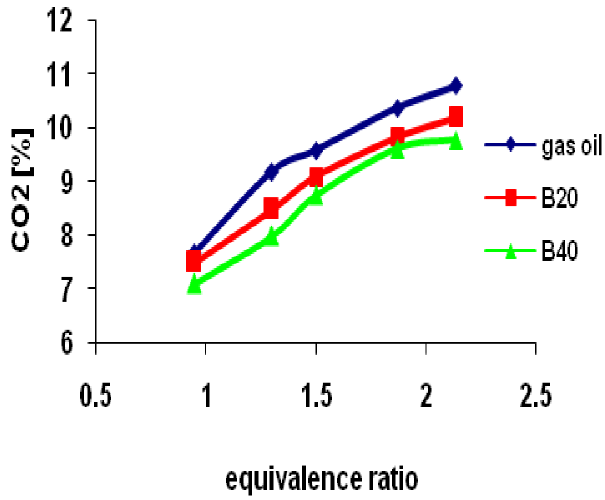

Fig. 5 Effect of equivalence ratio on CO_2 emission for burner fueled with biodiesel and gas oil

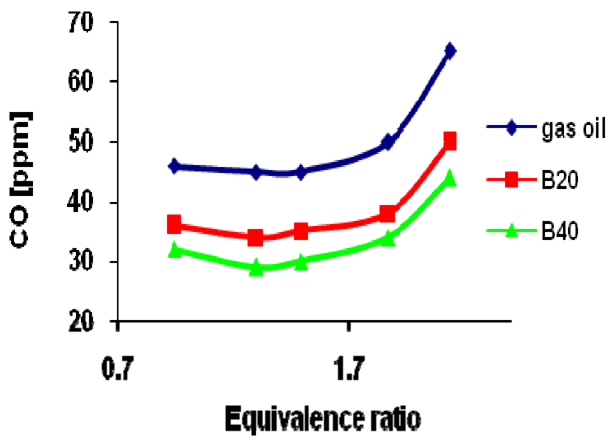

Fig. 6 Effect of equivalence ratio on CO emission for burner fueled with biodiesel and gas oil

Fig. 5 demonstrates the mole fraction percentage of CO_2 at different equivalence ratio. The CO_2 percentage of mole fraction has risen up with increase of equivalence ratio from 1 to nearly 2.5. CO_2 emission has declined from B0 to B 40 in every equivalence ratio. Figure 6 present an upward trend of CO emission at various equivalence ratios. A strong reduction of CO emission is recorded for biodiesel fuel from B0 to B40.

IV. Conclusion

An experimental investigation on combustion characteristic and emission pollutants of biodiesel and oil gas is carried out. All tests is conducted using several percentage of biodiesel at different equivalence ratios. Based on the presented results, the following conclusions may be drawn:

- Temperature of exhaust gas has increased with increase of percentage of biodiesel from B0 to B40.
- Temperature has reached its peak around $\varphi=1.3$, then it has declined.
- No_x emission has increased when using biodiesel as fuel. The physical properties of biodiesel could cause such an advance.
- Using biodiesel, CO and CO_2 emission has decreased in contrast of using gas oil as fuel.
- CO and CO_2 emission has risen up with increase of equivalence ratio.

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