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Effects of Palm Biodiesel Blends on Fuel Consumption in Fire Tube Boiler

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Abstract. Biodiesel application in boiler is basicly potential due to the combustion system tends to be simpler than compression ignition as performed in diesel engine. The various tests on combustion facilities showed that the use of biodiesel will increase the fuel consumption. This study was conducted in a fire tube boiler, with heat input rate of 60.000 kCal/hr and 3 bars of pressure, using palm biodiesel. A series of test shown that the combustion behavior in boiler was strongly possible influenced by some changes in physical properties of the fuel. The blends was varied in 10, 20, 30, 50 and 100% of biodiesel in mixture with petrodiesel. The fuel consumption was likely similar or slightly lower than petrodiesel when the fuel used in lower blends (less than 20%). In higher blends, the fuel consumption was increased up to 17%. The rate of consumption was relatively lower at average 9,4% in half load mode of the boiler operation rather than full load.

Introduction

Boilers are essential in industrial, commercial, and institutional sectors and it comprises a significant component of energy consumption. Boilers use a heat source through the combustion of fuel to produce hot water or steam. One of the common fuels used in boilers is petroleum diesel, although the latter portion of its use continues to decline along with the depletion of oil reserves and its price fluctuations on the world market.

Biodiesel is an alternative fuel which has a great opportunity to replace petroleum diesel, because it has many properties in common with diesel oil. Mostly, biodiesel utilization in anykind of engines is mixed with petroleum diesel. Many studies showed that 20% or less of biodiesel blends with petroleum diesel is the optimum blend to gather better effect of emissions reduction and does not require any special adjustments on engine operating conditions or modifications to the engine and fuel lines as expressed by [2,6,10,18].

In terms of engine performance, one of the technical considerations that are affected due to the use of biodiesel is the specific fuel consumption. Various test results indicate that specific fuel consumption is affected by the heating value as determined by the physical properties of the fuel [4,10,16,18]. The studies showed that the source of raw material for biodiesel and its blends in petroleum diesel affects t[i]he properties of the fuel so that it will definitely affect the fuel consumption. Though admittedly, the use of biodiesel in diesel engines give some advantages in oil lubrication and emission reduction, but there are still doubts for boiler users, especially for commercial and industrial sectors, due to concerns about equipment compatibility, engine performance and product sustainability and cost. Due to the limited study of biodiesel effects on industrial/commercial boilers, it is important to study how the changing properties of palm biodiesel blends will affect particularly to the fuel consumption on the boiler.

Fuel Consumption in Diesel Engine and Boilers

Specific Fuel Consumption (SFC) is the amount of fuel that can be converted into mechanical energy by a machine. SFC in diesel engine is determined by the ability of the combustion process in the engine, which is chemically influenced by the amount of these physical properties of fuels, such as heating value and cetane number. The SFC increases with increase in percentage of biodiesel in the blends due to the lower heating value of biodiesel [11].

The SFC of biodiesel and its blends are slightly higher than that of diesel at high engine loads, and keep almost same at lower engine loads [7-8]. Nagaraju *et al*. (2008) reported the use of 20% soybean methyl ester mixed to 80% petroleum diesel oil (B20) on the High Speed Direct Injection (HSDI) diesel engine. They showed that the specific fuel consumption was higher than B0, it is attributed to the lower heating value of biodiesel and late release of energy in the expansion stroke [14]. Moreover, Xue *et al*. (2011) summarized that fuel increase of consumption when using biodiesel [10,11,16,18], but this trend will be weakened as the reduces proportion of biodiesel fuel in the blends.

The increase in biodiesel fuel consumption is mainly due to its low heating value, as well as its high density and high viscosity. The different feedstock of biodiesel with different heating value and carbon chain length, or different production processes and quality, also have an impact on engine economy [18]. Jaichandar et al. (2011) have concluded the specific fuel consumption when using a biodiesel fuel is expected to increase by around 14% when there is unchanged for a fixed engine operation mode [10]. The loss of heating value of biodiesel must be compensated for with higher fuel consumption. The same trend was shown by Avecedo *et al*. (2011), it showed that at the same engine speed, SFC values with biodiesel were 18% higher than petroleum diesel oil [1]. In the meantime Jagadish *et al*. (2011) have confirmed that higher quantities of blending leads to increase of in fuel consumption, but upercharging operation resulted in reduction in fuel consumption [9]. Wirawan *et al*. (2008) reported that power and torque for biodiesel blends was higher than pure biodiesel (B100) but lower than pure petrodiesel fuel (B0) [17]. Fuel viscosity has impacts on injection and combustion, which continue to affects a power loss of the engine [17,11]. The loss of power is related to fuel consumption [1,11,18].

Some tests of biodiesel application in industrial, commercial or institutional boiler are very limited. Miller (2008) was tested animal and soy-based biodiesel in fire tube boiler, they reported some significant reductions in emissions of pollutants, but they did not find a significant difference to the efficiency of the boilers, without giving detail informations about the effects on fuel consumption [12].

Materials and Methods

Biodiesel used in this study were transesterified palm oil and its blends with petroleum diesel oil No.2. The characterization of fuel performed to determine the physical properties of palm biodiesel and the blends in some variations of blending composition. Fuel properties are evaluated focused on the properties associated with the combustion performance and the hypothetical effects on fuel consumption, such as density, viscosity, calorific value, flash point and cetane number.

Biodiesel tested in the study was respectively of 10%, 20%, 30%, 50% in proportion with petroleum diesel oil. B10 to show the mixing of 90% petroleum diesel with 10% palm biodiesel, and so on. The fuel tested in a small industrial fire tube package boilers, vertical cilinder models with heat capacity 60,000 kCal/h and operates at a pressure of 3-6 bar. The flue gas analysis was conducted by a gas analyzer IMR 1400 that is connected to the end of the boiler's chimney. Data was collected in every 10 minutes. The rate of fuel consumption is done by observing the volumetric rate from fuel tank supported by stopwatch.

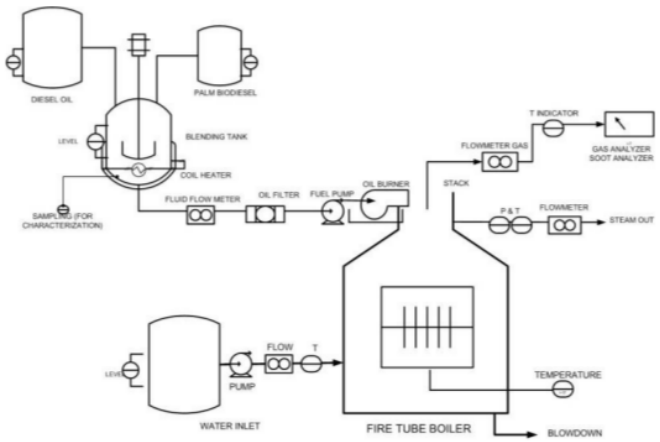

Fig. 1. Experimental Set Up

Results & Discussion

Fuel and Fuel Blends Characteristics.

As a common results, the comparison of biofuels with diesel oil No. 2 displayed relatively similar trend, where the density of palm biodiesel is 7.58% higher than diesel oil, while the viscosity and the cetane number is 0.53% and 33.5 % higher than petroleum diesel, otherwise, the calorific value is 8.56% lower. The low heating value of biodiesel is normally less than mineral diesel due to the fuel-bound oxygen [4]. The difference in the physical properties of both fuel is due to the different chemical structure. Cetane number of biodiesel is higher than diesel oil and among other biodisel from different raw materials. It is probably caused by the longer carbon chain of palm oil and higher oxygen contents in the blends. The analysis of the physical properties of biodiesel and its blends tend to exhibit physical properties whose value changes linearly with the increase of biodiesel in the blend. Analysis of the physical properties are in shown in Table 3.

Table 3. The physical properties of Palm Biodiesel Blends

properties	units	fuel blends of palm biodiesel and diesel oil				
		B10	B20	B30	B40	B50
density	kg/m^3	860,78	864,56	868,34	872,12	875,9
viscosity	mm^2/sec	4,5024	4,5048	4,5072	4,5096	4,512
heating value	kJ/kg	39692,8602	39088,4	38483,94	37879,48	37275,02
flash Point	^oC	168,7	170,4	172,1	173,8	175,5
cetane Number	-	52,52	55,04	57,56	60,08	62,6

Effects on Fuel Consumption.

The effect of physical properties of the biodiesel blends on fuel consumption in firetube boiler is shown in Figure 2. The more biodiesel in the blends was indicated the more fuel consumed. In this study the use of neat biodiesel (B100) consumes 17% more fuel than diesel oil. It can be explained that if the fuel was injected, the ignition was delayed due to the fuel must pass through the stages of evaporation and mixing with the incoming air into the combustion chamber. The high viscosity and density is likely to lead to a longer ignition delay due to the larger fuel droplet particles that affect the distribution of fuel in the cylinder combustion chamber. In addition, the lower calorific value of biodiesel is due to oxygen bonds, it means that fuel will release less energy, so that the engine operation require more fuel.

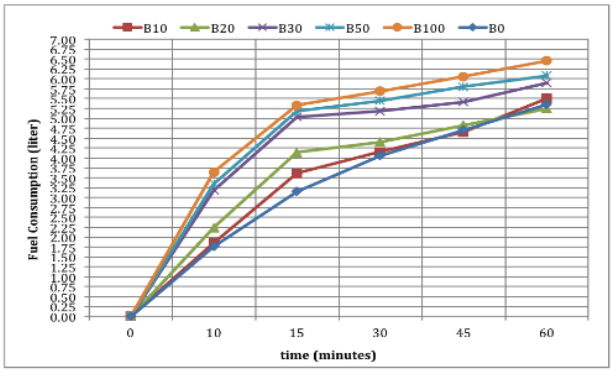

Fig. 2. Effects of combustion time on fuel consumption with various Biodiesel Blends in Boiler

In case of burning the lower blends (below 20%) of biodiesel, the fuel consumption was similar or slightly lower than petrodiesel. It is due to the optimal combustion behavior occurred, wherein the cetane number and higher heat of combustion parameters was compromized to the negative impacts of poor atomization due to higher viscosity and lower heating value of the fuel blends. The higher heat of combustion is influenced by the higher density of the fuel.

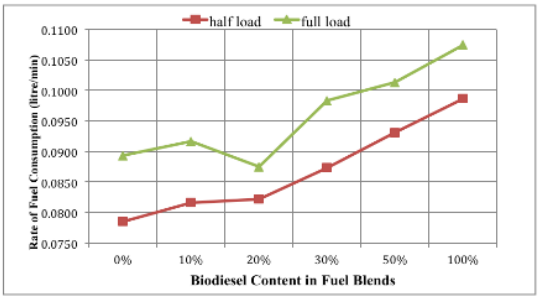

Fig. 3. Effects of Biodiesel Blend use in Firetube Boiler at half and full load

A variation of the boiler load was conducted by opening the steam control valve. The half load was set by adjusting the steam distribution valve, so that the steam production send to steam drum (in the plant) was lower than optimum conditions (full load). The effects of boiler load on the rate of fuel consumption are shown in Figure 3. In this study, at half load boiler operation, the fuel consumption rate was averagely 9.4% lower compared to at full load mode.

Meanwhile, when neat palm biodiesel used (B100) the fuel consumption rate in half load mode was decreased 8.16%. It is possibly affected by the less amount of water to be heated, so that the temperature gradient needed for heating the water in the cylinder was lower so that the supply of fuel required for combustion through pumping fuel into the burner automatically become fewer.

Conclusion

A series of test in the boiler with palm biodiesel as fuel showed that at lower biodiesel blends the fuel consumption was likely to be similar or lower than petrodiesel. However, for higher biodiesel blends, there was an increase in fuel consumption of up to 17%.

In stage of combustion, the atomization and ignition is influenced by the interaction of the fuel physical properties parameters such as viscosity, density, cetane number and calorific value. Palm biodiesel has a higher viscosity with a lower calorific value, but on the other hand it has a higher cetane number, and the higher densities that lead to a higher heat of combustion per volume of fuel. The better combustion behaviour of palm biodiesel performed in boiler possibly minimized the negatif effects on fuel consumption.

The variation of boiler operation mode, indicated that the rate of fuel consumption of palm biodiesel in boiler at half load mode was 9,4% lower than full load.

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