The Optimum Conditions of Fire Tube Boiler fuelled with Biodiesel-Diesel Oil Blends

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Abstract

A various tests of biodiesel use in any combustion facility were conducted in order to comply the government mandatory regarding stages of biodiesel utilization, especially in industrial and commercial sectors. The higher biodiesel blends that applied in the boiler show a significant effect on emissions reduction but followed by a reduction in boiler efficiency and an increase in fuel consumption. This study was carried out using palm oil-based biodiesel in the fire tube boiler with 3 bar operating pressure and heat input of 60,000 kcal/hour. In this study, an adjustment scale of the fan damper is conducted in order to control the amount of excess air that enters the combustion chamber. This study showed that the more percentage of biodiesel in fuel blends, the amount of combustion air must reduced. This mechanism was effective through fine-tuning of the fan damper scale. This adjustment may result an increase in efficiency of 0.64 to 2.6%.

Keywords : biodiesel, boiler, combustion, fan damper scale, efficiency

Introduction

Boiler is one of the industrial equipment that consumes fuel intensively. The fuel used in the boiler is considered by its steam demand, fuel prices, availability and supply guarantees. The number of oil-fired boilers in the industrial and commercial sector is much smaller than other types of fuel such as natural gas, coal and biomass, but in terms of the volume of consumption, the amount of diesel fuel used for boiler are still high. The use of petroleum oil should continue to be reduced due to teh limited availability of fuel supply and oil price fluctuation concerns. One effective way is by increasing the absorption of biodiesel utilization in all sectors of users.

The application of biodiesel in all sectors is already mandated by Ministry of Energy and mineral resurces Regulation No. 25 of 2013 which represents a change of typical rules No. 32 of 2008 regardings the staging of biofuels utilization and trade system. For the industrial and commercial sectors, the use of biodiesel target is 5% in 2013, 10% at the beginning of 2016, 20% in 2020 and 25% in 2025. Nowadays, the application is still not effective as targeted, it represented by facts that there are very limited users which already used biodiesel as its boiler fuel. This condition is influenced by engine compatibility issues and biodiesel prices concerns.

Biodiesel use in Combustion Facilities

Some biodiesel use testings on boilers have shown good effects on reducing emissions (Komariah *et al.,* 2013), but the other hand it perfomed some lower boiler performance rather than diesel oil. In a lower blends of biodiesel (<20%), it can be used directly without modification (Batey, 2003; Demirbas, 2008), but there is still no guarantee against potential problems that may arise related to the engine performance effects at the long term utilization of biodiesel.

Miller (2008) have tested the use of biodiesel from soybean oil in boiler. He stated that the boiler efficiency tend to be lower (1.3%) than diesel oil. Wirawan *et al.,* (2008) tested palm based biodiesel in automotive diesel engine showed the same tendency. According to Xue *et al.,* (2011) and Lapuerta (2008); the more biodiesel blends, the engine power tends to decrease so the Break Specific Fuel Consumption (BSFC) increases as well. The increase in BSFC tends to be accompanied by a decrease in thermal efficiency.

Air Combustion control is one effective way to anticipate the decline in boiler efficiency. According to Bhatia (2010), the excess air will consume energy through heat absorption. This will cause a reduction in efficiency. Veski (2002) stated to maintain the maximum boiler efficiency, boiler operating conditions was necessary to set on optimum air ratio. Meanwhile, Krishna (2001) concluded that for the biodiesle blends less than 30%, there wass no influence on the performance of the boiler, as long the process run in steady state conditions. The excess air was controlled by setting the air fan damper. In these conditions, CO and NOx emissions reported awake remained lower than fuel oil due to lower ignition temperature. Meanwhile, Murni (2011) mentioned biodiesel blends heating could make a better atomization so it possibly perform a good effect also on the efficiency and a decrease in fuel consumption.

To realize the compliances in biodiesel utilization mandatories, especially in industrial or commercial boilers, it needs to be organized a series of tests on the boiler to obtain optimum conditions the use of biodiesel-diesel oil blends through a variation of the combustion air quantity.

Methods

This study was conducted on the fire tube boiler used in the biodiesel pilot scale plant in Sriwijaya University, Inderalaya South Sumatera. Figure 1 showed the boiler and apparatus used in the test.

Figure 1. Boiler, Oil Burner and Gas Analyzer

The boiler's technical data are presented in Table 1. Biodiesel used is the result of transesterification of palm olein blended with petroleum diesel produced by Pertamina refinery unit III. The variations of the incoming combustion air wass controlled by means of fine tuning the burner fan damper on scale of 4.0 to 5.0.

During the tests, boiler was operated in full load conditions. The fuel flow rate was set constant and the combustin process carried out for 60 minutes after the boiler to reach steady state at a pressure of 3 bar.

Table 1. Experiment Boiler Specifications

Description	Specifications
Type	SB 60 MMT-Fire Tube
Model	Cylinder Vertical
Heat input Capacity	60.000 kCal/h
Working Pressure	3 Bar
Temperature	150 ^{o}C
Burner Type	W-Monarch Size 1-3
Operating Hours	1200 hours/year
Manufacturing year	2008

Results & Discussion

As occurred in several studies in diesel engine, the more biodiesel content in fuel blends in boiler fuel showed a significant decrease in emissions of CO, NOx, SO_2. Figure 2 showed the change in emissions from the utilization of biodiesel- diesel oil blends in boiler.

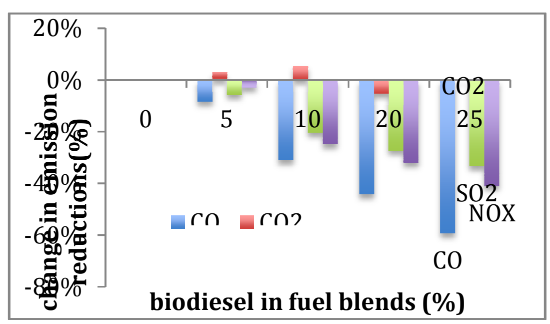

Figure 2. The change in emissions from the utilization of biodiesel blends in boiler

Most of studies stated that NOx emission from biodiesle blends combustion in diesel engine perofes higher NOx emission. In this study, we found that NOx emission was average 25,3% lower than diesel oil. The result was in line with study by Ghorbani (2011) when they used sunflower biodiesel in an experimental boilers. Wirawan *et al.,* (2008) was found a lower level of NOx emissions in automotive diesel engine exhaust gas. The lower NOx emissions level was contributed to the high cetane number of biodiesel that is able to promote complete combustion. Palash (2013) stated that biodiesel can cause a decrease in the adiabatic flame temperature. This condition may potentially reduce the risk of thermal NOx formation. In this study, the decrease in NOx emissions is correlated with the cetane number of palm biodiesel blends that on average 16% higher than diesel oil. The level of NOx emission in the boiler was not affected by the increase in exhaust gas temperature.

Boiler efficiency was calculated based on heat loss (indirect method). In base conditions (boiler fueled with diesel oil) the boiler efficiency was 87.5%. The utilization of 5-25% biodiesel blends in the fire tube boiler causes an increase in average heat loss of 9.71% which resulted a decrease in boiler efficiency at average of 1.39%. This condition goes along with increasing the temperature of the exhaust gas on average of 5.96%. The effect of percent of biodiesel blends on the boiler efficiency is shown in Figure 4.

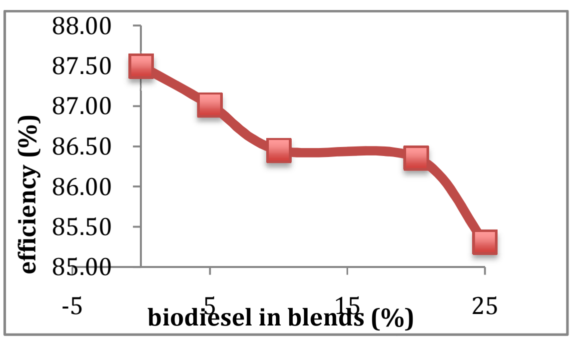

Figure 3. Effects of percent of biodiesel blends in diesel oil on boiler efficiency

The combustion air was varied through fan damper scale arrangement. The measurement of O_2 level in exhaust gas was conducted in order to quantify the combustion air enter to the combustion chamber. The O_2 level was changed by the tuning of fan damper scale. The effects of biodiesel content in fuel blends on efficiency was shown in Figure 3. The ambient temperature was range at an average of 28 °C with humidity 0.3 kg/kg air. The average wind speed was set constant of 3.8 m/sec.

The optimum fan damper scale was related to the optimum excess air combustion that supplied to the combustion chamber in boiler (Showers, 2002). Based on O_2 concentrations in the exhaust gas, the excess air supplied through oil burner for each scale of fan damper of 4,0, 4,3, and 4,6 was 71,13%, 85,54 % and 119,37% respectively. This excess air influenced by the burner injection pump system used in boiler which was set on fuel rich mode. In case of boiler design, the fuel rich mode needed higher excess air rather than theoritical air to complete perfect combustion, it was required a higher excess air more than theoritical air to complete the combustion.

The variation of fan damper scale was not effected significantly on the changes in emissions of CO, NOx and SO_2. This conditions showed that emissions quantity was dominantly influenced by the fuel characteristics rather than air combustion arrangement or boiler operating condistions. The effects of fan damper scale variation on boiler efficiency was presented in Figure 4.

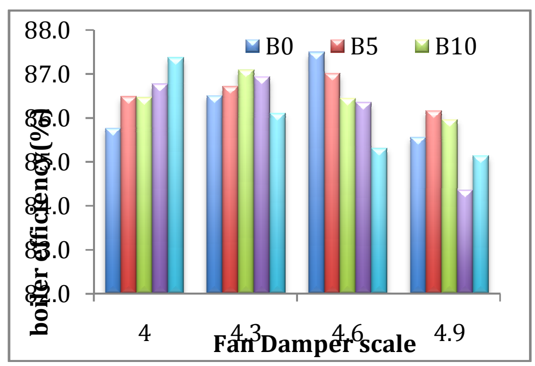

Figure 4. Effects of fan damper scale variation on boiler efficiency for each biodiesel blends

The fan damper scale indicated a mechanical system arrangement in entrance flow of combustion air. The reduction in scale means that the valve on the damper was not open widely. It was corresponded to reduced of incoming air flow rate. The amount of combustion air required in burning biodiesel blends is reduced due to the increased of oxygen content in biodiesel. This condition lead to some differences in specific physical properties of the blends so it will affects the biodiesel-diesel oil combustion behaviour.

The observations in Figure 4 showed that the maximum efficiency for the use of B5, B10, B20 and B25 can be achieved through fine-tuning of the fan damper scale. The adjustments performing a different requirement in excess air considering the characteristics of each fuel blends. More biodiesel in blends was found optimum in lower scale of fan damper.

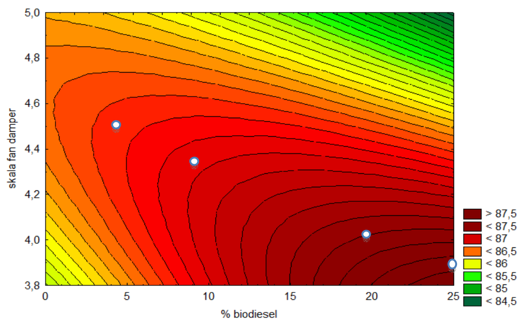

Figure 5. Boiler efficiency as function of percent of biodiesel blends and fan damper scale

Through observations in Figure 5 it is concluded that the maximum efficiency at each percent of biodiesel in fuel blends can effectively occurred with a different scale of fan damper. The use of B10 was effective at the interval scale from 4.2 to 4.4, while the use of B20 was likely to generate maximum efficiency on the fan damper scale at interval of 4.0 to 4.2 and the optimum use of B25 on a scale of 3.8 to 4.0.

Table 2. Boiler efficiency comparison between base condition and optimum fan damper scale

Fuel	Base Condition		Optimum Condition		changes (%)
	scale	efficiency (%)	scale	efficiency (%)	
B5	4,6	87,02	4,6	87,02	0
B10	4,6	86,45	4,3	87,09	0,64
B20	4,6	86,25	4,0	86,67	0,42
B25	4,6	85,31	4,0	87,37	2,06

Table 3 presented a comparison of the efficiency of the boiler is achieved on the fan damper scale changes. On the use of biodiesel by 10-25% blends, the fan damper scale adjustment corresponded to the excess air reduction at average of 9.2%. This reduction affected to an increase in the average boiler efficiency at average of 1%, where the increase was accompanied by a decrease in exhaust gas temperature an average of 7.67 ° C (45.8 ° F). Compared with a existed rule of thumb for oil-fired boilers in general, an 1% increase in boiler efficiency is achieved with a reduction of 15% excess air and flue gas temperature 40 ^{o}C.

Conclusions

The use of biodiesel-diesel oil blends in fire tube boiler can cause a decrease in boiler efficiency. It can be anticipated with the fan damper scale adjustment which is associated with excess air supplied. The greater percent of biodiesel in fuel blendsthe less excess air is required, or the smaller scale fan damper that need to be adjusted.

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