Applied Mechanics and Materials
ISSN: 1662-7482, Vol. 660, pp 402-405
doi:10.4028/www.scientific.net/AMM.660.402

Submitted: 2014-07-04
Revised: 2014-07-24
Accepted: 2014-08-12
Online: 2014-10-31

Optimum Excess Air for the Utilization of Palm Biodiesel Blends in Fire Tube Boiler

Susila Arita Rachman[1,a], Leily Nurul Komariah[1,b]

[1]Department of Chemical Engineering Sriwijaya University, Inderalaya Indonesia
[a]susila_arita@yahoo.com, [b]leilydiaz@yahoo.com

Key words: excess air, fan damper scale, optimum combustion, palm biodiesel

Abstract. Biodiesel has great potential to be applied in a variety of combustion engines, such as boiler. The excess air control in the combustion process plays an important role to produce an ideal combustion performance. The changes in the physical properties of the fuel due to the use of palm biodiesel or its blends affect the amount of required air to the combustion chamber. This study was conducted in a package type fire tube boiler with a design pressure of 3 bars and heat capacity of 60,000 kCal/hour. Palm biodiesel blends were set as boiler fuel with composition of 10%, 20%, 30% and 50% in diesel oil. Fan damper scale is part of the burner system that is charge to regulate the air flow into the combustion chamber. The fan damper scale was set in the range of 4.0-4.9. For higher blends of biodiesel, the fan damper was optimum in lower scale (4.0 or less). More biodiesel in blends, less combustion air was needed to enter. Hence, the excess air of palm biodiesel combustion in fire tube boiler was in range of 57-66%.

Introduction

Boiler is one of the mainstay technology for generating heating or process energy. Among several types of boiler, the packaged fire tube boiler has proven to be highly efficient and cost effective. Fire tube boilers are typically the smallest units, which less than 10 metric million Btu per hour in capacity. Most of boilers take various types of fuel, such as coal, diesel oil, natural gas or solid biomass.

Biodiesel is recognized as a potential fuel with many beneficials effects, especially in emission reduction. Due to it is most produced through trans-esterification reaction, biodiesel has a higher oxygen content than petroleum diesel, so it can promote complete combustion [7]. The higher oxygen content can improve the homogeneity of oxygen in the combustion thus increasing the efficiency of combustion [3]. In addition, biodiesel has a higher Cetane Number, so it can shorten the ignition delay time and accelerate combustion time [2,10].

Palm oil is known as one of biodiesel feedstock which is very potential to develop in Indonesia. Palm biodiesel shows a significant higher cetane number, viscosity and density, but it has a relatively lower calorific value. The potential use of biodiesel in boilers is still technically doubted due to some considerations related to engine compatibility and combustion performance. So that it is necessary to know the optimum quantity of combustion air when the palm biodiesel applied in the fire tube boiler.

Biodiesel Combustion and Excess Air

The complete combustion will take place when the proper amounts of fuel and air are mixed for the correct amount of time under the appropriate conditions of turbulence and temperature [1]. Practically, to achieve complete combustion, it is necessary to increase the amount of combustion air to the process to ensure the burning all of the fuel. The amount of air that must be added to make all energy is retrieved is known as excess air. The amount of excess air available changes the O_2 and CO_2 levels in the flue gas, which are important indicators of excess air and furnace efficiency [6].

Diesel oil are mostly a mixture of very heavy hydrocarbons, which have higher levels of hydrogen and less carbon, therefore it requires less combustion air to achieve complete combustion

[1]. On the other hand, biodiesel is also known as an oxygenative fuel due to it has higher oxygen contents, which 10-11% higher than diesel oil. The existence of oxygen in the fuel could promote the perfect combustion, so the required combustion air in combustion zone is changed. Nagi et al., (2008) stated that palm oil methyl ester contains inherent oxygen which helps to oxidize the number of gaseous by-products. More oxygen during combustion will raise bulk temperature [9].

A test on residential boiler using soybean biodiesel conducted by [8] stated that CO emissions was increased in low excess air. While, Hosseini *et al.*, (2010) was using a mixture of oil gas and biodiesel in a furnace, they reported that the flue gas temperature was increased by the increase of biodiesel contents in the fuel [5]. Ghorbani *et al.* (2011) was studied effects of sunflower biodiesel on experimental boiler with a variation of energy level of fuel and fan damper number. They concluded that the combustion with lower level of energy was more efficient. The increase of rate of combustion air caused a decrease in combustión efficiency and a high CO emissions [4]. As former finding, the amount of combustion air required depends on the characteristics of fuel. Due to the changes in physical properties, the biodiesel blend use in boiler could change the required air to achieve complete combustion through some adjustment.

Methods

The experimental was conducted using a fire tube boiler with a vertical cylinder type 3 bar operating pressure of the heat capacity of 60,000 kCal / hour. This boiler uses oil burners with fully automatic pressure atomizing (Monarch Oil Burner Size 1). Burner is equipped with water pressure damper on the fan side mounted with an arbitrary number scale. Temperature on boiler room is monitored by placing the temperature indicator on the main body of the boiler and boiler's stack. The content of CO_2, CO, and the residual O_2 in the flue gas was evaluated using gas analyzer with IMR 1400. The boiler was operated in full load mode during the test, while data was collected in every 10 minutes. Biodiesel used in this study is palm oil methyl ester (POME), it were added to the industrial diesel oil with composition of 20%, 30% and 50%. The blends were labelled respectively as B20, B30 and B50.

Result and Discussion

In the early stages of boiler conditioning, the variation of the combustion air supply through the fan damper adjustment was set on the scale interval at 4.0 - 4.9. Oxygen level at flue gas was set as indicator of the air quantity entered in the combustion chamber. The fuel analysis resulted that biodiesel has a beneficial properties for better combustion performance. The palm biodiesel has 76% higher of oxygen content and 30% higher of centane number compared to petroleum diesel oil.

Effects on CO and CO$_2$ levels in Flue Gas

In ideal combustion, the higher excess air creates lower amounts of CO and greater CO_2. The optimum quantity of air combustion was indicated form the scale where performing the minimum levels of CO and maximum levels of CO_2 as shown in Fig. 1a and 1b. For diesel oil combustion, in scale of 4.6 the optimum air shutter set. The subsequent of air to the chamber influence a decrease levels of CO_2 and CO. A similar trend was performed by combustion tests of B10 and B20, where the optimum air intake was set on scale of 4.3. At this condition, the level of CO from B20 combustions was lower compared to B10. At higher blends of biodiesel (B50), more combustion air show elevated levels of CO and a reduction of CO_2. The profile showed in Fig 1a and Fig 1b indicate the optimum scale of fan damper or air combustion supply for each blends as summarized in Table 1. The residual O_2 in a flue gas was also monitored to confirm the previous results.

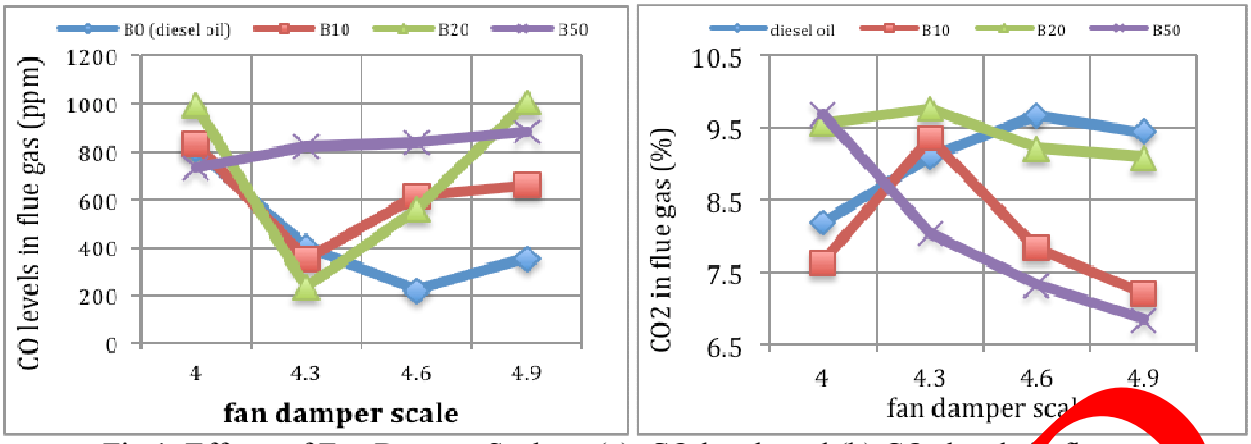

Fig 1. Effects of Fan Damper Scale to (a). CO levels and (b) CO_2 levels in flue gas

Table 1. Optimum Scale for Combustion Air Intake

Fuel	Fan Damper Scale	% O_2 in flue gas	excess air supplied (%)	actual mass air supplied (kg/kg oil)
B0 (diesel oil)	4.6	7.850	59.66	22.252
B10	4.3	8.300	65.4	22.788
B20	4.3	7.650	57.30	21.439
B50	4.0	8.105	62.854	21.449

**) by calculation, % excess air supplied = %O_2 in flue gas *100/(21-%O_2)*

The optimum excess air supplied for each blend was respectively 55.3%, 57.3%, and 62.8%.The amount of excess air indicate the burner system used in this boiler was fuel rich mode, so it takes a lot more excess air to achieve the optimum combustion.

Effects on Boiler Room and Flue Gas Temperature

The excess air arrangement affects the temperature of boiler room and the exhaust gas, due to the air can absorb the heat of combustion. A combustion with less air supply or over fuel will cause an increase in exhaust gas temperature. In general, the use of biodiesel blends in fire tube boiler can cause a decrease in the temperature of the boiler room and flue gas compared to petroleum diesel. In Fig. 2, the more air used in diesel oil combustion tends to increase the temperature of the boiler and exhaust gas. In case of B20 combustion, more excess air which exceeded the optimum scale of the stoichiometrical air combustion may lead to decrease the boiler and flue gas temperature. A test of B10 showed the uncertain trend that should be studied further. In the use of higher blends of biodiesel, when the air intake to the combustion chamber is beyond the optimum amount of excess air, it caused a reduction in exhaust gas temperature.

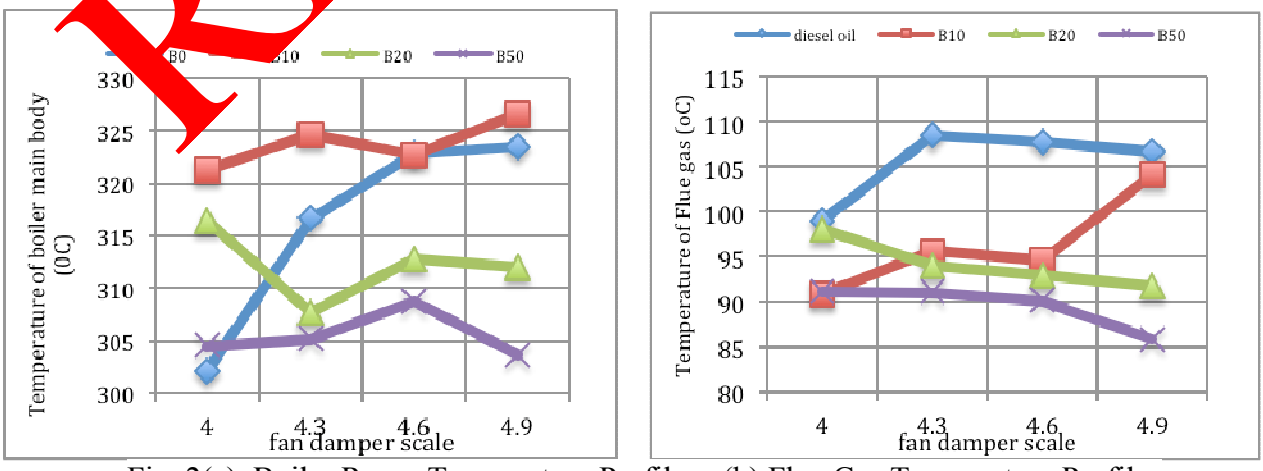

Fig. 2(a). Boiler Room Temperature Profiles , (b) Flue Gas Temperature Profiles

Conclusion

Palm oil biodiesel can be applied to the fire tube boiler with several adjustments in combustion parameters, one of the important thing is the amount of excess air. The adjustment is possibly conducted by tuning the fan damper scale on the burner system by considering the levels of CO, CO_2 and residual O_2 in the flue gas. The excess air has to be adjusted lower when the higher blends fuel applied in fire tube boiler. Due to the differences in physical properties, the more biodiesel in fuel blends, the required air is getting less. The exhaust gas temperature and boiler room tend to decreased by the amount of excess air entered to the combustion chamber of the fire tube boiler.

References

[1] M. Biarnes : *Combustion*, E-Instrument. Web (April, 2012), http://www.e-inst.com/.../E-Instruments-Combustion-Booklet-2009.pdf

[2] M. Boyd : *The Autoignition Properties of Biodiesel Fuels,* University of Adelaide (2007).

[3] A. Demirbas ; *Relationships derived from physical properties of vegetable oil and biodiesel fuels*, Fuel vol 87 (2008) p. 1743-1748.

[4] A.B. Ghorbani : *A comparative study of combustion performance and emission of biodiesel blends and diesel in an experimental boiler*, Applied Energy *vol 88* (2011) p. 4725-4732.

[5] S.B. Hosseini, K. Bashirnezhad, A.R. Moghiman, Y. Khazaei, N. Nikoosal : *Combustion Characteristic and Pollution Emission of Gas Oil and Biodiesel*, World Academic of Science, Engineering and Technology vol 48 (2010),p. 304-307.

[6] T. E. Jiru, B.G. Kaufman, K.E. Ileleji, D.R. Ess, H.G. Gibson, and D.E. Maier : *Testing the performance and compatibility of degummed soybean heating oil blends for use in residential furnaces*, *Fuel vol 89* (2010), p. 105-113.

[7] M. Lapuerta, J.M. Herreos, L.I. Lyons, R. Garcia-Contreras, and Y. Brice : *Effect of the alcohol type used in the production of waste cooking oil biodiesel on diesel performance and emissions*, *Fuel vol 87* (2008), p. 3161-3269.

[8] Massachusetts Oilheat Council & National Oilheat Research Alliance : *Combustion Testing of A biodiesel Fuel Oil blned in residential oil Burning Equipment*, Energy Research Center Inc. (2003).

[9] J. Nagi, S.K. Ahmed, and F. Nagi : *Palm Biodiesel an Alternative Green Renewable Energy for Energy Demands of the Future*, *CCBT 07* (2008) 79-94.

[10] K. Sivaramakrishnan and P. Ravikumar: *Determination of Cetane Number of Biodiesel and Its Influence on Physical Properties*, ARPN J. Eng and App Sci. Vol. 7 (2012), p. 205-211.