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by Yohandri Bow

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Analysis of Air Fuel Ratio on Combustion Flames of Mixture Waste Cooking Oil and Diesel using Preheating Method

Yohandri Bow[1], Sahrul Effendi[1], Ahmad Taqwa[2], Gilang Rinditya[1], Muhammad Yori Pratama[3], Rusdianasari[4]*

[1] Energy Engineering Department, Politeknik Negeri Sriwijaya, Jl. Srijaya Negara Palembang, 30139, Indonesia
[2] Electrical Engineering Department, Politeknik Negeri Sriwijaya, Jl. Srijaya Negara Palembang, 30139, Indonesia
[3] Chemical Engineering Department, Universitas Sriwijaya, Indralaya, Indonesia
[4] Renewable Energy Engineering Department, Politeknik Negeri Sriwijaya, Jl. Srijaya Negara Palembang, 30139, Indonesia
*Corresponding Author: rusdianasari@polsri.ac.id

Abstract. Fossil fuels are a non-renewable energy source results in depletion of fossil fuel reserves. Utilization of used cooking oil as an alternative fuel is one solution to overcome this problem. This study objective is to design a stove fueled by waste cooking oil and determine the optimum air flow rate and fuel flow rate in combustion. This study uses the used cooking oil as the main fuel, and diesel fuel as a mixture with a mixture of 100% used cooking oil, used cooking oil 80:20, 70:30, and 60:40 to diesel fuel. Fuel valve opening variations used are ¼ open, ½ open, ¾ open, and fully open, while the variation in air flow rate used is 14.91; 19.24; 27.64; and 31.28 m/s. The fuel samples used were tested for the heating value, flash point and fire point, fuel density, and water fuel ratio (AFR) analysis and water boiling test (WBT). The results showed that used cooking oil had a heating value of 37,231.11 kJ/kg, flash point 289ºC, and fire point 305ºC. To achieve optimum AFR conditions (12-16:1) at a fuel flow rate of 2.5 mL/min (¾ valve open) and an airflow rate of 27.64 m/s, and WBT analysis with 221 mL fuel consumption requires a long time boiling water 16'23" minutes. Conversion of used cooking oil to kerosene fuel is 1 liter of used cooking oil equal to 0.3 liters of kerosene.

1. Introduction

Used cooking oil is waste from the frying process originated from many types of cooking oil such as corn oil, vegetable oil, refined oil [1]. According to the World Oil Database (2016), Indonesia's cooking oil production is 33.4 billion tons. Based on these data, that Indonesia has a high amount of cooking oil utilization, as well as the waste it generates.

The waste from the used cooking oil can be recycled into many products such as a floor cleaner, bath soap, liquid soap, as a plant fertilizer, and as an alternative fuel (biodiesel), but there are several uses of used cooking oil used as recycled cooking oil [2]. The consumption of non-industrial or household palm cooking oil by the Indonesian people currently reaches 4,444 million tons per year, of which 16.35% is consumed in the form of packaged cooking oil, and 73.65% in the form of bulk cooking oil [3].

Utilization of used cooking oil as an alternative fuel is not new but still has the potential to further development, one of which is used as biodiesel. Utilization of used cooking oil that is still being developed is direct use as fuel. This use is an attractive option to reduce the cost of raw materials and processes compared to biodiesel [4-8].

The manufacture of cooking oil-fueled stoves is carried out using the pressurized tank and burner with the preheating method and fuel injection control. The applied waste cooking oil is processed by adding kerosene 75%, 50%, and 25% by volume. However, this research still has shortcomings that are still using fossil fuels, poor pressurization pump methods, and must increase fuel turbulence so that combustion is better [9, 10].

This study designs cooking oil-fired stoves using the fuel atomization method and the fuel preheating method. Fuel atomization method is a method of dripping fuel in front of compressed air causes atomized fuel grains, to be smaller granules so that the combustion process occurs more quickly. This compressed air is produced by a blower. The method of preheating the fuel is bypassing the fuel through the heater before entering the combustion chamber, so the fuel temperature rises before entering the burner [15-16]. The technology for utilizing used cooking oil as fuel is intended to reduce the use of fossil fuels as the main fuel and reduce the energy crisis [17-18].

2. Methods and Materials

Research on the use of used cooking oil as fuel on the stove was carried out using variations in air flow rate and variations in fuel flow rate, as a mixture of fuel used diesel. Air and fuel flow rate variations produce a ratio between the air and the fuel used or the so-called air-fuel ratio. Sampling data analysis is the analysis of density, and hotspots and flashpoints. Retrieval of data analysis on the experiment is the water boiling test (WBT) analysis. The results of the used cooking oil stove design in Figure 1.

Figure 1. Waste cooking oil-fueled stove

3. Result and Discussion

3.1. Fuel Sample Analysis

The experiment is started by the preparation of samples of raw materials (waste cooking oil) received from micro industries such as the frying food industry. Variations of the sample are done in t mixing raw materials with diesel fuel, with variations of 80:20, 70:30, and 60:40. Mixing with diesel fuel is to optimize the ignition of combustion fire, to ensure the fuel gets more combustible. Variations of the sample are shown in Table 1.

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Table 1. Fuel Analysis Results

No	Sample	Parameters		
		Density (gr/mL)	Flashpoint (ºC)	Fire point (ºC)
1	Waste cooking oil 100%	0.90	289	305
2	Waste cooking oil 80:20 Solar	0.90	273	281
3	Waste cooking oil 70:30 Solar	0.89	255	263
4	Waste cooking oil 60:40 Solar	0.89	221	229

This fuel analysis aims to determine the value of each sample that supports its use as a fuel used in cooking oil-fired stoves.

3.2. Fire and Flash Points

The flashpoint is the temperature at which the sample is burned, and the fire is marked by the appearance of sparks. The fire point is the temperature at which the sample is burned as the fire occurs. Flash and fire point experiments were carried out to find out the flashpoint temperature and the hotspot temperature of the sample.

Based on the measurement results of 100% used cooking oil has the highest flash point compared to other samples, 289°C, while the lowest flashpoint is 60:40 diesel used cooking oil sample which is 221 °C. The mixture of used cooking oil with diesel has a lower flash point than 100% used cooking oil fuel. The higher the composition of diesel fuel to the mixed fuel, the lower the flash point produced.

The measurement results of 100% used cooking oil fire point, the highest flash point compared to other samples is 305oC, while the lowest fire point is 60:40 diesel used cooking oil sample which is 229oC. The mixture of used cooking oil with diesel has a lower fire point than 100% used cooking oil fuel. The higher the composition of diesel fuel to the mixture of fuel, the lower the point of fire produced.

The relationship of the flashpoint and fire point is the flashpoint determines the temperature value of the sample ignites into the fire, while the fire point determines the temperature value of the sample burned to fire. Fire point ignites continuously if exposed to a flame, so before the point of fire, the first point of fire is the flashpoint [10]. This indicates that the higher the flashpoint, the higher the point of fire.

The flashpoint is affected by cetane numbers in the fuel. Diesel fuel which has a cetane number of 45 - 48 makes the fuel combustible, so used cooking oil also burns. The greater the composition of diesel fuel in a mixture of fuel, the cetane number in the mixture fuel increases so that the flashpoint of a fuel sample is lower and the sample is easier to burn.

3.3. The Relationship of Variation of Fuel Flow Rate to Fire Temperature in Analysis Air Fuel Ratio (AFR)

The relationship of the variation of fuel flow rate to the temperature of a fire in various fuels with fixed variables is the airflow rate shown in Figure 2. The relationship of fuel variation to fire temperature in various fuel samples based on Figure 2 can be analyzed that the waste cooking oil mixture 60: 40 diesel has the highest fire temperature compared to other fuels, while waste cooking oil 100% has the lowest flame temperature compared to other fuels. The higher the composition of diesel fuel to the mixture, the higher the temperature of the fire produced. The heating value of the fuel influences the high temperature of the fire from the fuel. The higher the heating value of the fuel, the higher the temperature of the fire produced.

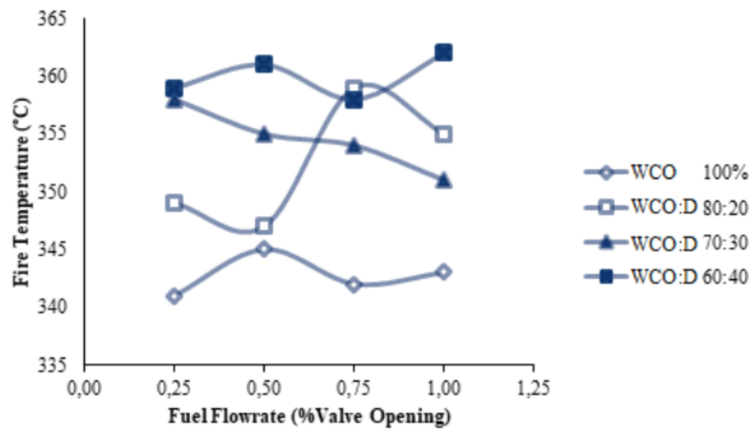

Figure 2. Relationship of Fuel Flow Rate Variation to Fire Temperature

The relationship of the variation of fuel flow rate to the temperature of the fire is experiencing fluctuations, and it is seen in Figure 2 that the 70:30 diesel used cooking oil mixed fuel has decreased flame temperature for the variation of fuel flow rate used. Based on Figure 2, there are valve openings 1/4 open, ½ open, and fully open with the highest flame temperature at 60:40 diesel used cooking oil mixture, while at open valve ¾ open the highest flame temperature at 80:20 used cooking oil mixture solar.

3.4. Water Boiling Test (WBT) Analysis

3.4.1. The Relationship between Water Boiling Time and Fuel in WBT

The duration of boiling water in the WBT analysis of various experimental samples in Figure 3. From Figure 3, 100% used cooking oil has the longest boiling time of about 983 seconds while the fastest is 60:40 diesel used cooking oil sample, which is about 341 seconds. The mixture of used cooking oil with diesel has a shorter boiling time compared to used cooking oil. Mixed fuel samples have faster water boiling time records because the heat value of the sample is high; the fire temperature to be generated is also high. High fire temperatures accelerate the process of heating the water to boiling.

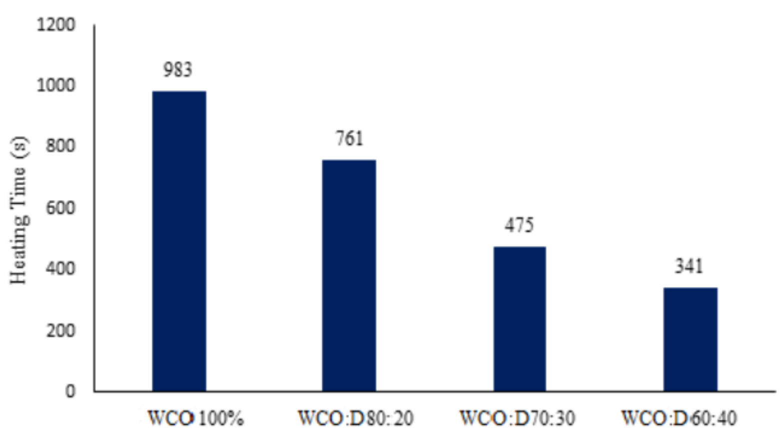

Figure 3. Water Boiling Time Diagram in WBT Analysis

3.4.2. Relationship of Fuel Consumption to Fuels used in WBT

The fuel consumption of each fuel sample is shown in Figure 4. Based on Figure 4, 100% used cooking oil samples in the WBT analysis have higher fuel consumption compared to mixed fuel samples, while 60:40 diesel used cooking oil mixed fuel samples have the lowest fuel consumption compared to other fuels. This is because the heating value of the used cooking oil sample is low, so that the resulting fire temperature is also low. Low fire temperature causes water heating to be longer and result in more fuel consumption.

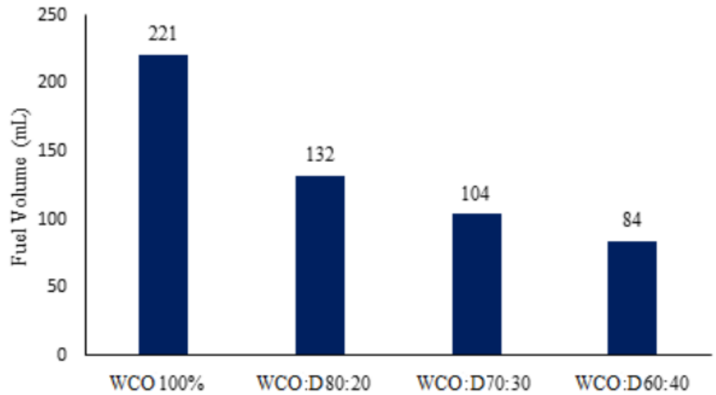

Figure 4. Fuel Consumption Diagram in WBT Analysis

3.5. Analysis of Cooking Oil Burner Efficiency Stoves on Water Boiling Test (WBT)

The energy efficiency of the stove to the variation of fuel used in WBT is shown in Figure 5. Based on Figure 5, the 60:40 diesel used cooking oil mixed fuel has the highest energy efficiency of 8.45% compared to other fuels, while the lowest efficiency at used cooking oil 3.45%. The higher the composition of the diesel fuel mixture, the higher the efficiency, since the energy produced from the mixture fuel (heating value) is more utilized with a small volume of fuel consumption. The higher the calorific value of the fuel, the lower the volume of fuel consumption used for heating water.

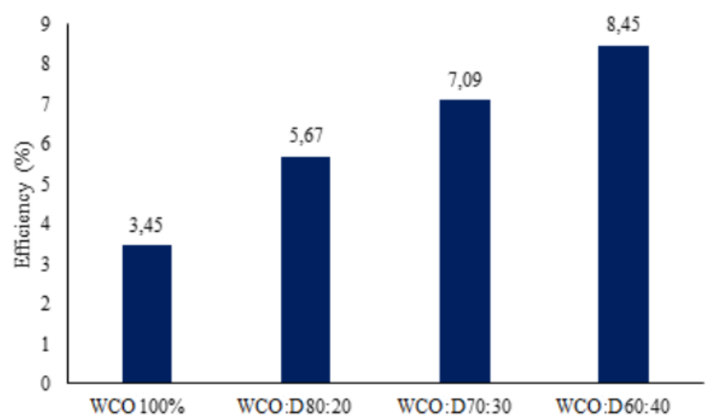

Figure 5. Stove Efficiency Diagram for Fuel Variations

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3.6. Economic Analysis

Break-Even Point (BEP) analysis is needed to find out the time of breakeven or when the return of capital and costs have been incurred to produce a number of products. In the BEP analysis, it is known that the capital to produce the product is Rp. 3,091,515.00/day, while the savings created by the product are Rp. 44,000.00/day. The time needed to reach BEP is 71 days or 2 months 11 days. The BEP point on 71 days is the savings made every day if it continues to be collected can replace capital in the manufacture of equipment. Fuel conversion analysis is needed to find out the exchange rate of waste cooking oil with commonly used fuels (kerosene) and biodiesel. The calculation results obtained that 1 liter of used cooking oil equal 0.3-liter kerosene equal 0.32 liter of biodiesel.

4. Conclusions

The optimum standard AFR of 12:1 produce maximum energy, while the AFR of 16:1 produces maximum economic value for combustion. On used cooking oil stoves to achieve optimum conditions using a fuel flow rate of 2.5 mL/min (valve opening ¾ open), while the airflow rate used is 27.64 m/s. Mixing the fuel using diesel fuel aims to increase the calorific value of the fuel and increase the cetane number so that it is easy to ignite the fire and produce a proper combustion temperature. The optimum composition is 70:30 diesel used cooking oil mixture. The combustion flame depends on AFR, and the highest temperature is at AFR 10:1 with a temperature of 357ºC and the higher the AFR, the resulting flame is getting bigger and longer. The energy efficiency of a stove using 100% used cooking oil is 3.45%. Conversion of used cooking oil to kerosene fuel, which is 1 liter of used cooking oil is equal to 0.3 liters of kerosene.

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