EXPERIMENTAL STUDY OF WASTE VEGETABLE OIL AS A BIOFUEL

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Abstract

Biodiesel is an alternative fuel for diesel that is produced by chemically combining waste vegetable oils with an alcohol to form methyl esters. This paper reviews the history of biodiesel development, two strokes engines performance, and the technology to utilize the fuel without problems. The scopes of the projects are to produce the fuel and the analysis on combustion process by using waste vegetable oil. Extensive research and analysis projects have shown the waste vegetable oil can produce energy when it been tested using the bomb colorimeter and also to find the final product from the reaction of waste vegetable oil with alcohol using combustion chamber. Through this research, the basic knowledge of how combustion process works using waste material and how to improve it can be gained.

Keyword: Biodiesel , Combustion , Waste vegetable oil , Methyl ester.

Introduction

Biomass is a renewable energy source. Biomass waste materials, such as agriculture residues, wood processing residues, waste paper and yard waste, are valuable green power resources. While carbon dioxide is emitted during biomass combustion, an equal amount of carbon dioxide is absorbed from the atmosphere during the biomass growth phase. Therefore, use of biomass does not cause global warming. Besides, biomass contains virtually no sulfur, so it emits no sulfur dioxide, which is a precursor of acid rain. [1] Most of the biopower plants in the world use direct-fired systems. They burn biomass feedstocks directly to produce steam, which is captured by a turbine, and then converted into electricity by a generator. The steam can also be used for certain manufacturing processes. [4]

Waste vegetable oil (WVO) is converted into biodiesel fuel in a process called transesterification. Transesterification is a reaction that uses a catalyst (NaOH) and an excess of methanol (a type of alcohol) to convert WVO (triglycerides) to biodiesel (methyl esters).

However, the transesterification reaction is sensitive to the presence of free fatty acids (FFA). FFA's are the result of oil degradation. As a result, WVO tends to have higher levels of FFA's than pure (unused) vegetable oil. Because FFA's can slow or stop the transesterification reaction, it is important to know the amount of FFA's present in each batch of WVO so adjustments can be made to the transesterification process to neutralize the excess FFA's. [2]

The same chemical that is used to catalyze the reaction - NaOH, can neutralize FFA’s. Therefore, in order for the transesterification reaction to proceed, enough NaOH will be needed to neutralize any FFA's in the oil in addition to the amount of NaOH that is used as a catalyst.

This research is to obtain data for combustion process, bomb calorimeter and viscometer. These processes were done to show result of experimental study to produce fuel using waste vegetable oil.

Methods

APPARATUS:

Natrium Dioxide, methanol, waste vegetables oil (WVO)

Methods or procedure:

1. In this experiment we choose waste vegetable oil (WVO) as our product that follows our objective to make the fuel from the waste material. We choose waste vegetable oil because of the material is easy to find and cheaper compare to the straight vegetable oil (SVO). Moreover the waste material has high levels of free fatty acids (FFA) and need catalyst to neutralize the mixture in waste material.[5]

2. The catalyst **(**NaOH**)** is dissolved into the alcohol by vigorous stirring in a small reactor this process we call as Titration process .The oil is transferred into the biodiesel reactor and then the catalyst/alcohol mixture is pumped into the oil and the final mixture is stirred vigorously for 2 hours. A successful reaction produces two liquid phases: ester and crude glycerol. Crude glycerol, the heavier liquid will collect at the bottom after several hours of settling. Phase separation can be observed within 10 minutes and can be complete within 2 hours of settling.

3. Complete **s**ettling can take as long as 20 hours. After settling is complete, water is added at the rate of 5.5 percent by volume of the oil and then stirred for 5 minutes and the glycerol is allowed to settle again (depends on the amount that we used).

4. After settling is complete the glycerol is drained and the ester layer remains. Washing the esters is a two- step process, which is carried out with extreme care. A water wash solution at the rate of 28 percent by volume of oil and 1 gram of tannic acid per liter of water is added to the ester and gently agitated. Air is carefully introduced into the aqueous layer while simultaneously stirring very gently. This process is continued until the ester layer becomes clear. [5]

5. Finally the ester is ready to use for the combustion process.

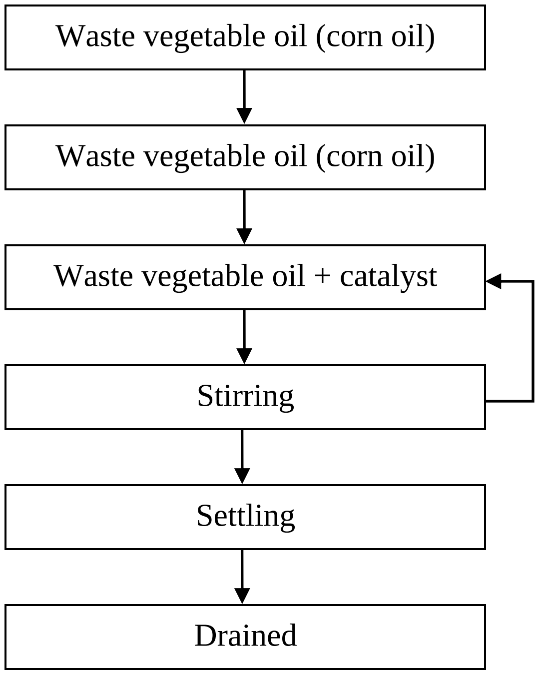

Figure 3.1: Process to produce methyl ester using Natrium hydroxide

EXPERIMENTAL AND RESULT

Two experiment is conducted in determine the physical properties of waste material and analysis on combustion process of waste.

A) Combustion chamber

B) Viscometer

Combustion or burning is a complex sequence of exothermic chemical reactions between a fuel and an oxidant accompanied by the production of heat or both heat and light in the form of either a glow or flames. Direct combustion by atmospheric oxygen is a reaction mediated by radical intermediates. The conditions for radical production are naturally produced by thermal runaway, where the heat generated by combustion is necessary to maintain the high temperature necessary for radical production.

In a complete combustion reaction, a compound reacts with an oxidizing element, such as oxygen or fluorine, and the products are compounds of each element in the fuel with the oxidizing element. The minimum amount of air needed for the complete combustion of fuel is called the stoichiometric or theoretical air. The amount of air used in combustion process is also expressed in term of the equivalence ratio or known as air fuel ratio. The equation can be written in form of formula:. [10]

BALANCING THE COMBUSTION EQUATION

Balancing the combustion equation:

$$2CH_3OOCR + 3.5\ (0_2 + 3.76\ N_2) \rightarrow 4CO_2 + 3H_2O + 13.16\ N_2 + 2R$$

Carbon (C) : 4

Hydrogen (H) : 6

Oxygen (O) : 11

Nitrogen (N_2) : 13.6

R : 2

Air Fuel Ratio

$$AF = \frac{m_{air}}{m_{fuel}} = \frac{(NM)_{air}}{(NM)_C + (NM)H_2}$$

Therefore, 8.947 of air are used to burn each kg of biodiesel during this combustion process. h^o_f = enthalpy (298.15 K) = - 408800 kJ/kmol

Table 4A: Data of combustion

Substance	h^o_f kJ/kmol	h_{301k} kJ/kmol	h_{298k} kJ/kmol	h_{1140k} kJ/kmol
$CH_3OOCR(\ell)$	-408800	-	-	-
0_2	0	9000.6	8682	36314
N_2	0	8984.9	8669	34760
H_2O (g)	-241820	-	9904	41780
CO_2	-393520	-	9364	50484

$Q_{out} = \sum N_r (h^o_f + h - h^o)_r - \sum N_r (h^o_f + h - h^o)_p$

Q_{out} = 883,747 kJ/kmol CH_3OOCR

Thus 883,747 kJ of heat is transferred from the combustion chamber for each kmol (2 kg) of methyl ester. This corresponds to 883,747/2 = 441837.5 KJ of heat loss per kg of methyl ester. Then the rate of heat transfer for a mass flow rate of (0.144 kg/min) for the methyl ester becomes

$Q_{out} = \dot{m} \times q_{out}$

= (0.144 kg/min) (441873.5 KJ/Kg)

= 63629.78 KJ/ min.

= 1060 KW

VISCOMETER

THEORY

Moving in oil would be even more difficult, as can be observed by the slower downward motion of a glass ball dropped in a tube filled with oil. It appears that there is a property that represents the internal resistance of a fluid to motion or the fluidity and the property is the viscosity. . [1]

RESULT OF VISCOMETER

Temperature test (T=40 ^oC, T=100 ^oC)

Methyl Ester and waste vegetable oil (WVO) test

1. Use glass capillary viscometer

Set temperature T=40 ^oC

Time allowed should not be less than 200 s, for manual viscometer.

200 s = 3 min 20 s

Table 4B: Types of glass capillary viscometer: at T=40 ^oC

Type of capillary viscometer	Calibration constant , c (mm^2/s^2)	Temperature, T (^oC)	Time, t (s)	Viscosity, v (mm^2/s)	Type of Oil
(200, U157)	0.1053	40	34.2	0.060021	Methyl Ester
(U75, K970)	0.00728	40	666.0	4.8485	Methyl Ester
(200, U165)	0.097946	40	496.2	48.60	WVO
(300, 59W)	0.24427	40	190.8	46.60	WVO

For glass capillary viscometer (U75, K970),

V= Calibration constant x time

= 0.00728 mm^2/s^2 x 666.0 s

= <u>4.8485 mm^2/s</u>

Sample calculation for finding viscosity for waste vegetable oil (WVO),

For glass capillary viscometer (200, U156),

V= Calibration constant x time

= 0.097946 mm^2/s^2 x 496.2 s

= <u>48.60 mm^2/s</u>

From the table 4B, it is find that the suitable and accepted glass capillary viscometer types are (U75, K970) and (200, U165)

Methyl Ester and waste vegetable oil (WVO) test

Set temperature T=100 ^oC

Table 4C: Types of glass capillary viscometer: at T=100 ^{o}C

Type of capillary viscometer	Calibration constant , c (mm^2/s^2)	Temperature, T (^{o}C)	Time, t (s)	Viscosity, v (mm^2/s)	Type of Oil
(200, U157)	0.1053	100	88.20	9.287	WVO
(U75, K970)	0.00728	100	25.80	0.187824	WVO
(200, U165)	0.097946	100	60.84	5.95903	Methyl Ester
(300, 59W)	0.24427	100	132	32.2436	Methyl Ester

DISCUSSION

In this experiment catalyst used in the process of producing methyl ester is NaOH. The ratio of catalyst used and product is 1:5.

From three experiments of combustion, all shown the combustions are complete combustion. Complete combustion process produce H_2O, CO_2 and N_2. The fuel use in this combustion chamber process is methyl ester. The quantities ratio of methyl ester ($2CH_3OOCR$) is 2 kmol and air 3.5(O_2 + N_2) is 3.5 kmol

The combustion balancing equation shown that 2 mol of methyl ester are needed to burn in complete combustion. The minimum amount of air needed for the complete combustion of a biodiesel is 8.947kg/air fuel ratio (refer equation 4.1) Thus, when a fuel is completely burned with the air fuel ratio, no uncombined oxygen will be present in the product gases. . [10]

The air fuel ratio also referred to as the chemical correct amount of air, or 100 percent of air fuel ratio. The enthalpy of combustion which represent the amount of heat released during steady -flow combustion process when 1 kmol (or 1 kg) of biodiesel is completely at the 298.15 K at 25 ^{o}C at 1 atm. Then the rate of heat transfer for a mass flow rate of (0.144 kg/min) for the methyl ester is 63629.78 KJ/ min. Control the air fuel ratio is important to determine the combustion process is complete or incomplete combustion.[11]

In viscometer experiment the viscosity between waste vegetable oil and methyl ester are quite different. The viscosity of methyl ester is lighter than the waste vegetable oil and it also can be clearly observe from its colour It also can be proof by the slower downward motion of oil (fluids) dropped in viscosity tube. The longest time need for the oil to drop from the first to the second timing mark of viscosity tube, so the higher viscosity of the substance.

The theoretical formula show the viscosity is proportional to time. In general, the viscosity of oil (fluids) depends on both temperature and pressure. When temperature increase to (T=100°C) the time taken for both substance are faster than the time allowance (200 s). This is because in a fluids form the molecules possess more energy at the higher temperature and they can oppose the large cohesive intermolecular forces more strongly. As a result, the energized fluids molecules can move freely. [8]

CONCLUSION

From experiment conducted it was found that the waste vegetable oil can be converted to biodiesel using the transesterification. Transesterification is a reaction that uses a catalyst (NaOH) and an excess of methanol (a type of alcohol) to convert WVO (triglycerides) to biodiesel (methyl esters). [1] The result from the combustion chamber and bomb calorimeter experiment shown that the methyl ester can produce energy when it is burned to critical temperature. Therefore the objective for this project is to investigate of waste material which potential alternative fuel and analysis on combustion process of waste material is achieved.

RECOMMENDATION

Some recommendation can be made in order to ensure the methyl ester is a pure biodiesel and can be functioning at high efficiency level. Firstly, improvement can be made by conducting microstructure analysis to determine the characteristic of biodiesel produced. Next, result can be improved by stirring the **catalyst (**NaOH**)** for more than 2 hours so that the mixture bonding will be distributed evenly. Then, one area that can be improvised is the filtering process. In the experiment only one process of filter was done. Multistage filtering is recommended to have the better methyl ester from crude glycerol.

There is room to be considered during the combustion process which is to investigate the quality of air during process. It is important to ensure the air excess from the combustion process is non toxic and environment friendly. The other suggestion is to do a further research on the potential of the methyl ester for lubrication.

The methyl ester can be tested to diesel engine to determine the performance of the engine and the combustion process.

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