Biodiesel Demonstration for Outreach and Education

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Student Paper Abstract

The demand for alternative fuels is growing, and green fuels can help meet this need. With the rising cost of oil per barrel and the increasing amount of vehicles daily on the road, renewable fuels can help offset fuel costs and aid the environment by reducing carbon emissions, and other harmful gases. Both biodiesel and ethanol are the current answer to the alternative question.

This paper will describe the development of a small biodiesel demonstration apparatus for educational purposes. The process includes biodiesel production, a working model engine demonstrator, and its implementation in outreach activities. The production process which covered Fall 2007 includes a homemade setup to make 1 liter batches of biodiesel. The model engine demonstrator is a simple diesel model airplane engine mounted on wooden display. Outreach activities will hopefully spread the news of green energy in a way larger scale automobiles cannot. This demonstrator will be able to go into classrooms and conventions with the option to perform experiments including power output, efficiency of various fuels, and possibly emissions testing.

Key Words

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Introduction/Background

Energy has become a key issue for the United States and the world. There is a growing need to transition gradually from fossil fuels toward new and emerging energy sources. Bioenergy, and specifically biofuel, has developed into an increasingly important component of the U.S. energy portfolio. "In 2007, the President set a goal of reducing gasoline usage in the United States by 20 percent in the next 10 years."[1] Fifteen percent will come from alternative fuels, which is constantly increasing in production. Great strides in research still need to be taken to ensure that biofuel implementation will increase, but not at the cost of the world's food sources. According to MSNBC, oil prices increased to a record $103 per barrel on Monday, March 3rd [2]. With diminishing stocks and increasing prices, alternative fuels are necessary.

To help pave the way for future energy solutions, people at all levels must be educated about current and future energy strategies. People must understand the need for new energy technologies, the uses for these technologies, and their own role in the energy solutions of the future. Research to support this claim is difficult to identify, but United States Energy Secretary Bodman stressed the importance of energy education for all Americans in his address to the Department of Energy Education Forum. He calls for educating Americans about the benefits of energy efficiency and renewable energy technologies, many of which were renewed and expanded in the Energy Policy Act of 2005 [3].

This project is part of a larger effort to promote energy literacy and education. Moving toward the energy landscape of the future requires exposing today's youth and public to new energy concepts and applications that will be required knowledge in years to come. To support this need, Professor Heather Cooper, Mechanical Engineering Technology department faculty and executive board member for Purdue's Energy Center at Discovery Park, has conceived and developed a collection of energy outreach and education activities, which include hands-on experiments in areas such as solar energy, wind energy, and hydrogen/fuel cells for a variety of youth, public, and university audiences. These activities have educated hundreds of people on energy concepts through more than a dozen distinct events in the past two years.

The overall goal of this project is to add biodiesel to Purdue's energy demonstration capabilities. Specific goals for the project are to successfully produce a quality batch of vegetable oil biodiesel, to build a working demonstration for implementation of the biodiesel, and to use the demo at outreach events.

Homemade Biodiesel Process

Biodiesel is a fuel made from vegetable oil that will operate in diesel engines. The method to produce biodiesel is fairly simple depending on the quality of oil used in the process, and the amount of fuel expected to be produced. The most important, and the easiest to acquire, ingredient is the vegetable oil. Just about any oil can be used including canola, coconut, peanut, and sunflower oil. Also, methanol and sodium hydroxide or potassium hydroxide are needed to react with the oil to produce biodiesel. These are all the necessary ingredients for making biodiesel, however, other items are needed to mix, measure, and store the processed biodiesel. Figure 1 below shows all the necessary tools needed to perform a one liter biodiesel experiment.

Figure 1. Equipment needs for homemade biodiesel

The chemical process of creating biodiesel involves taking a triglyceride (complex fatty acid) molecule, neutralizing the free fatty acids, removing the glycerin, and creating an alcohol ester [4]. The first part of the process is to mix warmed (to no more than 140°F) vegetable oil with sodium methoxide. Sodium methoxide is created by mixing liquid methanol and sodium hydroxide pellets, combined in a mason jar and mixed until the sodium hydroxide pellets are no longer visible. Then the warmed oil and sodium methoxide are added to a conventional blender and run on the lowest setting for about 30 minutes. Figure 2 shows the mixing biodiesel.

Figure 2. Blending biodiesel from oil and sodium methoxide

Next, the blender is turned off and the biodiesel is poured into mason jars for the settling process. Settling is necessary for at least 24 hours to separate the good biodiesel from glycerin, a by-product that can be purified and used in many different products like soap, toothpaste and makeup. Finally, the biodiesel may be washed by mixing water with it and oscillating until impurities are removed. Figure 3 compares a recently settled batch of biodiesel with a washed one. It can be seen that there is a clear separation between the biodiesel and glycerin in the left jar. Also, notice the difference in color; the washed biodiesel on the right is darker. For a neutral pH of 7 desired for cleaned biodiesel, visual examination should reveal an apple juice color. This cleaned biodiesel on the right is the final product which can be used in an engine.

Figure 3. Settled (Left) and Washed (Right) Biodiesel

The method described above is the final biodiesel production process for this project, however, seven months and many trials were performed to achieve this. The process is optimized to keep all ingredients pure as can be seen by the equipment list in Table 1 below. Notice both the sodium hydroxide and methanol need to be at least 95% pure. Also, pure vegetable oil rather than used oil makes it much easier to produce quality fuel. This avoids the complication of attempting to titrate the oil to ensure the right amounts of methanol and NaOH are used.

Table 1. Optimized Materials and Equipment List

1 Liter Vegetable Oil
6 grams Sodium Hydroxide (NaOH) 97%+ Pure
200mL Methanol (CH_3OH) 99%+ Pure
Blender
100mL Graduated Cylinder
1000mL Beaker
Thermocouple Type T
Scale (Accurate to .01g)
Hot Plate
3 Mason Jars
2 Liter Bottle

In addition to the purity of the ingredients, the exact composition of the sodium methoxide is important for biodiesel quality. The optimal combination of ingredients was determined through testing more than five different mixes of methoxide (as shown below in Table 2). The final solution, using 200 mL of methanol and 3.50 g of NaOH, is the control test shown.

Table 2. Various Quantities of Methoxide Ingredients

Control	**Test 3**
Methanol - 200mL	Methanol – 250mL
NaOH - 3.50g	NaOH – 3.50g
Test 1	**Test 4**
Methanol – 250mL	Methanol – 200mL
NaOH – 3.15g	NaOH – 3.00g
Test 2	**Test 5**
Methanol – 250mL	Methanol – 200mL
NaOH – 3.00g	NaOH – 3.25g

Failures in producing a good batch of biodiesel were numerous, but the major ones included the failure to obtain pure methanol and the improper measurement of ingredients. The first attempts at producing small batches of biodiesel used HEET® gas line anti-freeze as the methanol. After many incomplete reactions, it was discovered that the anti-freeze did not contain enough methanol to be effective. By obtaining an almost pure mixture of methanol, biodiesel was successfully produced. Improper measurement of the methanol was a difficulty that arose after the pure mixture was obtained. A beaker was used to measure the 200mL of methanol, and although the difference in liquid was small, the effects were noticeable in the final product. This failure was resolved by measuring with a graduated cylinder.

Biodiesel Demonstration Apparatus

Now that a process has been developed for optimized biodiesel quality, it is desired to use the homemade biodiesel in an educational activity. The demonstration apparatus for this purpose uses particle board as a base, 2"x2" boards to hold the engine mount, and a common model airplane fuel line and tank as can be seen in Figure 4 below. The engine is a Silver Swallow Compression Ignition Type Engine more commonly known as a diesel model airplane engine shown in Figure 4 on the left. These model engines do not use an electrical or glow plug ignition, so like a car diesel engine, it will ignite just by compression.

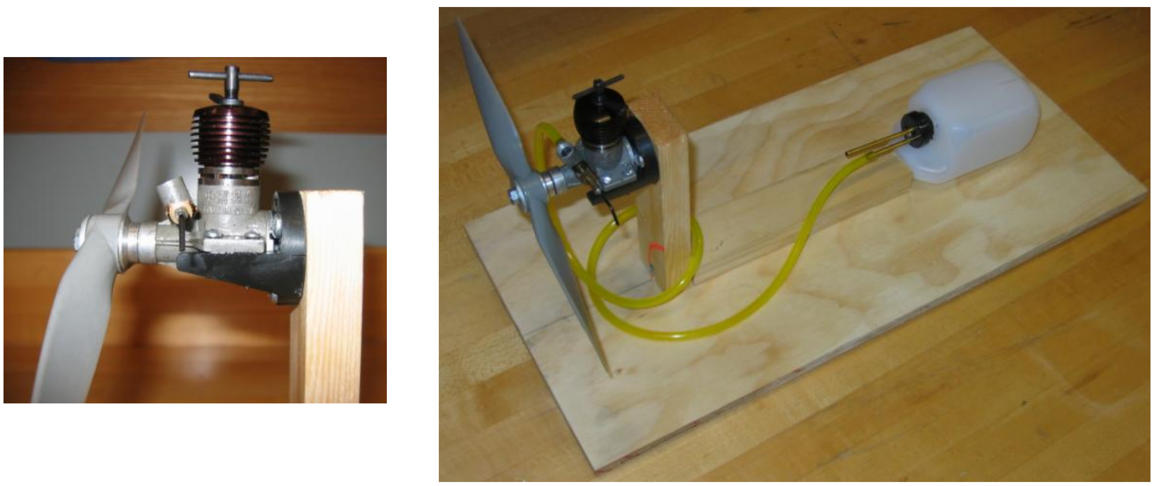

Figure 4. Biodiesel Demonstration Apparatus

The apparatus was developed with the goal of simulating the mounting on a real model airplane. The wooden frame will stabilize the rotating propeller and will somewhat absorb the vibrations from the engine. A heavy weight will need to be added once the engine is started to prevent the demonstration from moving from the thrust of the propeller. Testing has included using diesel petroleum fuel which has failed, most likely due to it not being combustible enough. Future tests, to be completed in March 2008, will include an equal mixture of ether, biodiesel, and kerosene oil, which is a fuel mixture similar to those used in model aircraft engines. If that run is successful, the ratio of biodiesel to other ingredients will increase until the biodiesel is the majority of the mixture.

Implementation of Biodiesel Demonstrator

The final stage of this project is to use the biodiesel demonstration apparatus in an educational activity for a youth audience. By the end of March 2008, the apparatus is expected to be running off either 100% of biodiesel or a majority of the solution being biodiesel. In addition, a method of testing power output, the efficiency of the engine using different fuels, and possibly emissions will be developed. It is expected that the biodiesel demonstrator will first be used with a preliminary youth audience in early April 2008.

Conclusions

A biodiesel demonstration apparatus is being developed to support energy education and outreach needs. Production of homemade biodiesel has been completed, through an optimized process developed over several months. A model aircraft engine was incorporated into a small-scale test stand to be used for demonstration. The engine is expected to be operational by late March 2008, and is expected to be used for an initial youth education audience in April 2008. While results from the biodiesel demonstrator are not available for this paper, it is expected to improve Purdue's portfolio of energy education activities and help promote alternative energy education at all levels.

Bibliography

[1] Systems Biology for Energy and Environment. DOE Mission Focus: Biofuels, Retrieved March 3, 2008 from http://genomicsgtl.energy.gov/biofuels/

[2] Business/Oil & Energy. Oil retreats from record after OPEC outlook, Retrieved March 4, 2008 from http://www.msnbc.msn.com/id/12400801/

[3] Energy Education Forum. Remarks prepared for Energy Secretary Bodman, January 5, 2006, U.S. Department of Energy.

[4] What is Biodiesel? Biodiesel resources, information, community & news, Retrieved March 4, 2008 from http://www.biodieselamerica.org/biodiesel101

Biography

Tony Huck is a senior in Mechanical Engineering Technology at Purdue University. He has been involved in energy outreach and education since May 2007 and has presented at many outreach events including Renewable on Parade held in September 2007 in Washington, Iowa. He plans to apply his knowledge of renewable energy into his future career.