BIOFUELS – PART 3: BIODIESEL BASICS

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Biodiesel is the easiest alternative fuel to implement. Very little change is required in regard to transportation, refueling infrastructure, and vehicles for it to be used. Biodiesel fits into a category of alternative fuels called biofuels. Biofuels can be defined as fuels that are derived from recently-living biological resources, and as such, are further categorized as renewable fuels. Biodiesel is to petroleum diesel what ethanol is to gasoline. This is the third in a series of articles about biofuels and will cover the basics of biodiesel.

What is Biodiesel?

A common misconception is that biodiesel is the same as raw vegetable oil. Although biodiesel can be, and usually is, derived from vegetable oil, vegetable oil must be chemically processed into biodiesel. Biodiesel is the name given to fatty-acid alkyl esters (long chains of carbon molecules attached to an alcohol molecule) when used as a substitute for petroleum based diesel fuel. Biodiesel contains no petroleum. Since it is derived from vegetable oils and other organic oils, it can be considered as a renewable fuel. Biodiesel can be burned in most compression-ignition (diesel) engines, either undiluted or mixed with petroleum diesel in any ratio, with little or no required engine modifications. By definition, biodiesel means 100% biodiesel. Mixtures of biodiesel and petroleum diesel are referred to as biodiesel blends and are designated as B2, B10, etc., with the number indicating the percentage of biodiesel in the blend. Blends of B20 and higher qualify for alternative fuel credits under the Energy Policy Act, but only B100 is recognized as an alternative fuel.

How is Biodiesel Made?

The main chemical process in the production of biodiesel is transesterification. Transesterification is accomplished by reacting an organic oil with an alcohol over a catalyst (usually sodium hydroxide or potassium hydroxide). The result of the reaction is a mixture of fatty-acid alkyl esters and glycerin. The other processes in biodiesel production include pretreatment for some feedstocks, clean-up of biodiesel and glycerin, and methanol recovery.

Feedstocks (the organic oil in the transesterification process) for biodiesel production vary widely. The most common feedstock is soybean oil. Others include sunflower oil, rapeseed oil, Chinese tallow tree oil, and recycled cooking oils and grease. One interesting and promising feedstock is algae. The oil yield from algae is much higher than from vegetable oils and it can be grown in non-farmland and non-forest areas.

How Does Biodiesel Compare to Petroleum Diesel?

Some of the important points of comparison between petroleum diesel and biodiesel are fuel economy, cetane number, emissions, cold weather performance, and lubricity.

Similar to the relationship of ethanol to gasoline, a particular volume of biodiesel contains less energy than the same volume of petroleum diesel; however, ethanol's disadvantage to gasoline is 32% whereas biodiesel's disadvantage to petroleum diesel is only about 10%. Less energy per volume translates into lower fuel economy.

The cetane number for diesel fuel is similar to the octane number for gasoline; both are a measure of the ignition characteristics of the fuel. Autoignition is the combustion of fuel which is not initiated by an external source. Gasoline engines have an external source of ignition (spark plugs); thus, autoignition is not desirable. The octane number measures the ability of gasoline to resist autoignition. A higher octane number corresponds to a greater ability to resist autoignition. Diesel engines do not have an external source of ignition, and thus rely on autoignition to ignite the fuel. The cetane number measures the ability of diesel fuel to autoignite quickly. Low autoignition time corresponds to smoother and more complete combustion, both of which are desirable. A higher cetane number corresponds to faster autoignition. Petroleum diesel in the U.S. typically has a cetane rating in the low 40s and biodiesel typically in the low 50s.

Biodiesel contains about 11% oxygen by weight. The oxygen in the fuel helps it to burn more completely which reduces exhaust emissions. B100 reduces hydrocarbon emissions by almost 70%, and carbon monoxide and particulate matter emissions by almost 50%. A B20 blend achieves emission reductions of 20% and 12% respectively. On the other hand, oxygenated fuels tend to increase emissions of nitrogen oxide. B100 and B20 increase nitrogen oxide emissions by approximately 10% and 2% respectively. Nitrogen oxide emissions contribute to the formation of ground level ozone. Research to lower or eliminate nitrogen oxide from biodiesel emissions is ongoing. Biodiesel is also more environmentally benign than petroleum diesel. It is non-toxic and contains no sulfur.

Biodiesel is at a disadvantage to petroleum diesel in cold weather. At low temperatures, wax crystals begin to form in diesel fuel. As the temperature further drops, the wax crystals will increase and can clog fuel filters and injectors and will finally gel and cease flowing. These same issues affect biodiesel, but at higher temperatures. The temperature at which diesel fuel begins to crystallize is called the cloud point. Petroleum diesel has a cloud point of around 5 º F. B100 and B20 have cloud points of about 35 º F and 15 º F respectively. Fuel additives can be used in petroleum diesel and biodiesel to lower cloud points and help alleviate the problem.

Diesel engine fuel pumps and injectors rely on the diesel fuel itself for proper lubrication. In the early 1990s, the EPA began mandating lower sulfur content in diesel fuel. When sulfur is removed, diesel fuel loses much of its lubricating ability. Biodiesel has better lubrication qualities than low sulfur petroleum diesel and can thereby help extend the life of diesel engine components that rely of the fuel for lubrication. Biodiesel can also be used as an additive to petroleum diesel to restore the lubricity lost from removing sulfur.

The next article will cover economics, vehicles, infrastructure, and other issues that address the viability of biodiesel as an alternative transportation fuel.

Sources

Anthony Radich, “Biodiesel Performance, Costs, and Use,” Energy Information Administration.
Alternative Fuels and Advanced Vehicles Data Center website (URL: http://www.eere.energy.gov/afdc/).
“Biomass Energy,” *Kirk-Othmer Encyclopedia of Chemical Technology*, 5th ed.