LUBRICATION AND VISCOSITY OF THE BIOETHANOL-BIODIESEL-BIOETHANOL BLENDS

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INTRODUCTION

The Department of Automobiles at the Technical University of Budapest has been searching the possibilities of using alternative fuels for a long time. The target vehicle of this investigation, a flexible fueled vehicle (FFV) has a single fuel tank, fuel system, and engine. The vehicle is designed to run on diesel oil and a mixture of bioalcohol, biodiesel and diesel oil, containing up 20% of biofuel. The engine and fuel system in a flex-fuel vehicle must be slightly adapted to run on bioethanol-biodiesel-diesel oil blends, as the biofuels are more corrosive. The vehicle running with the investigated blends offers its owner an environmentally beneficial option whenever the alternative fuel is available.

MAIN GOALS OF THE INVESTIGATION

The main goal of our investigation was to increase the renewable part in the bioethanol-biodiesel-diesel oil mixture. The most important point was to meet the standard requirements of diesel oil with the mixtures. The most significant parameters were the viscosity and the lucubration in this phase of the investigations. Our idea was that if these parameters can be met, there is no or very little need of adding any changes in the engines. It means that the mixture could be used in the normal everyday engines without major reconstruction in the engine.

With the help of the investigated mixtures, the EU directives and recommendations are to match. The EU Directive 2003/30/EC recommends for the EU member states to increase the biofuel proportion in the total amount of used fuels. It states that increased use of biofuels for transport is one of the tools by which the European Union can reduce its dependence on imported energy sources, as diesel oil or gasoline. The Directive 2003/30/EC determines the two following steps for the member states:

- „A reference value for these targets shall be 2 %, calculated on the basis of energy content, of all petrol and diesel for transport purposes placed on their markets by 31 December 2005."
- „A reference value for these targets shall be 5,75 %, calculated on the basis of energy content, of all petrol and diesel for transport purposes placed on their markets by 31 December 2010."

INVESTIGATED BLENDS

Diesel oil is produced from petroleum. As a hydrocarbon mixture, it is obtained in the fractional distillation of crude oil between 250 °C and 350 °C at atmospheric pressure. It is considered to be a fuel oil and is about 18% denser than gasoline. The density of diesel oil is about 850 grams per liter whereas gasoline has a density of about 720 g/l, or about 15% less. When burnt, diesel oil typically releases about 40.9 megajoules (MJ) per liter, whereas gasoline releases 34.8 MJ/L, also about 15% less. Diesel oil is generally more simple refinable than gasoline and often costs less (although price fluctuations often mean that the inverse is true; for example, the cost of diesel traditionally rises during colder months as demand for heating oil, which is refined in much the same way, rises). Diesel fuel, however, often contains higher quantities of sulphur. In Europe, emission standards and preferential taxation have both forced oil refineries to dramatically reduce the level of sulfur in diesel fuels.

Biodiesel refers to a diesel substitutable fuel, produced from biological sources. It is a processed fuel that can be used in diesel engine vehicles, which feature distinguishes biodiesel from the straight vegetable oils or waste vegetable oils used as fuels in some modified diesel vehicles. Biodiesel is a light to dark yellow liquid. It is practically immiscible with water, has a high boiling point and low vapor pressure. Typical biodiesel has a flash point of ~ 150 °C, making it rather non-flammable. Biodiesel has a density of ~ 0.8, less than that of water. Biodiesel, when uncontaminated with starting material, is regarded as non-toxic substance.

Biodiesel has a viscosity similar to diesel oil, the industry term for diesel produced from petroleum. It can be used as an additive in formulations of diesel to increase the lubricity of pure ultra-low sulfur diesel fuel. Much of the world uses a system known as the "B" factor to state the amount of biodiesel in any fuel mix, in contrast to the "E" system used for bioalcohol mixtures. For example, fuel containing 20 % biodiesel is labeled B20. Pure biodiesel is referred to as B100. It has a very high cetane number, up to 56 CN.

Bioethanol has less than two-thirds of the energy density of diesel oil, and has the same limitations as alcohol vehicles. The lower energy density implies that at equivalent engine efficiency, a pure-alcohol-fueled vehicle would travel half to two-thirds as far as a diesel oil-fueled vehicle using the same size tank. The 1999 model year flexible fueled vehicles using E-85 have a driving range of 200-300 miles. The range for these vehicles when using diesel oil is 320-440 miles. These energy density disadvantages can be compensated by certain improvements in efficiency. These can be carried out in spark ignition engines using alcohols, unlike with diesel oil. Pure ethanol can also cause starting problems in cold weather.

The ethanol has a cetane number 8, much lower than diesel oil's 50-55. The air need of the ethanol is app. 9 kg air per kg of ethanol (8.4 kg for the E93 ethanol and 7% water content fuel). This rate is lower than diesel oil, which has an air need of 14.5 kg. The lower air need means a possibility to increase the measure of ethanol without change the value of the lambda namely the engine optimizing.

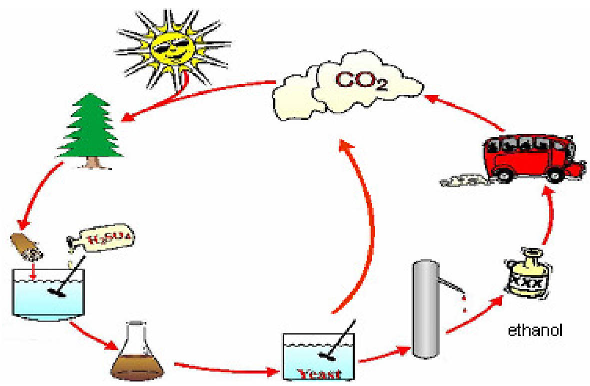

Figure. 1. The closed CO2 cycle of the biologically produced ethanol

Ethanol, as noted above, is a renewable resource that contributes nothing in itself to global warming concerns (Figure.1). Ethanol does not contain sulphur, which means it does not emit any sulphur dioxide. The NOx emission is lower on the grounds of the ethanol's higher vapor heat, which cools the combustion temperature. Ethanol vehicles require lines, hoses and valves to be resistant to the corrosion that alcohol can induce. Alcohol corrodes lead-plated fuel tanks; magnesium, copper, lead, zinc, and aluminum parts; and some synthetic gaskets (6). There are no additional changes needed in the distribution network for gasoline, diesel, and natural gas. The ethanol is denatured to prevent any misuse from ingestion.

During the investigation, no burning additives were used. Our speculation was that the abilities of the two renewable material are compensating each other. Another important factor was that we wanted to have the most uncomplicated mixture. 10 different mixtures have been investigated.

INVESTIOGATION RESULTS

Lucubration research

It was the High Frequency Reciprocating Rig (HFRR) method, developed by the Department of Mechanical Engineering, Imperial College, London that has emerged from the multitude of test methods as being the most capable for characterizing for lubricating behavior of diesel fuel [4].

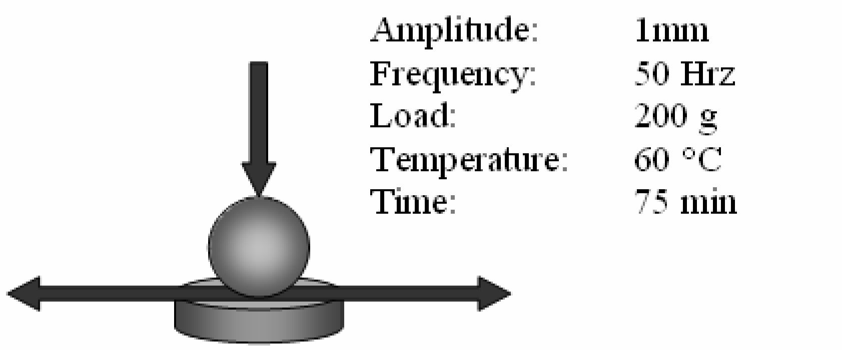

Figure. 2. HFRR method

The HFRR test method is a ball on cylinder test. The test equipment uses an electro magnetic vibrator to oscillate a ball specimen over small amplitude whilst pressing it against a fixed specimen, which is held in a small bath, containing the test fuel. The test takes 75 minutes.

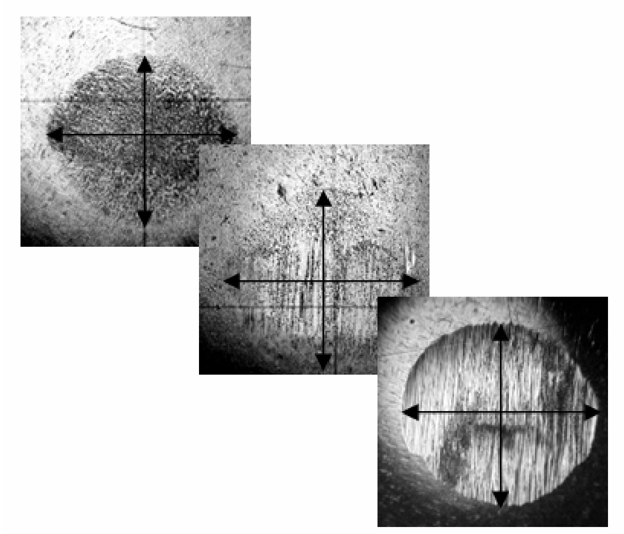

Figure. 3. Different wear scar diameters

After the test Wear Scar Diameter (WSD) on the ball specimen should be evaluated. The mean wear scar diameters are measured according to the ISO 12156. This standard requires to measure the detectable wear scar in ‘x’ and ‘y’ directions. The equivalent wear scar diameter is the arithmetical average of ‘x’ and ‘y’ values. This result should be modified respect of ambient temperature and humidity. Fuel lubricity is qualified according to this corrected mean wear scar diameter (WSD1,4).

Referring to this method the European Fuel Standard defines a maximal value of 460 μm. The precision of this method is rather poor, with reproducibility being 102 μm. Despite of its poor reproducibility and repeatability, the capability for selection and the easy practice made it internationally accepted test method and inserted into the European Fuel Standard (EN 590).

Table 1 – Lucubration measurement results

ID	diesel oil content	ethanol content	biodiesel content	lucubration (micron/mm)
CM_001	100	0	0	324
CM_002	80	10	10	279
CM_006	87,5	5	7,5	269
CM_012	94	2	4	221
CM_013	88	4	8	232
CM_015	0	0	100	218

The lucubration of the biodiesel is much better as the diesel oils. The lucubration of the three component blends are worthier if the ethanol content is increasing. In the aspect of lucubration the investigated blends are not critical in use them in diesel engines. But if the blends diverged, the local lucubration can be very different. The blend CM_002 without emulation additives can cause this.
The diesel oil’s lucubration after the Hungarian standard MSZ ISO 12156-1 at 60 ˚C can be maximum 460 μm. The measured blend can acchive this.

Viscosity measurements

Viscosity of the fuel blends has a great influence of the injection abilities. The biodiesel and bioethanol have a very different viscosity from the diesel. The viscosity of biodiesel is double; the bioethanol viscosity is only the one half of the diesels viscosity at 40 °C.

I had the preconception that biodiesel will emulsify ethanol and diesel oil and it will gear up the blend's viscosity.

The results of the viscosity measurements are seen in the Figure 6. It shows that ethanol viscosity was only measurable in lower temperature range only. At 74°C the bioethanol has reached the boiling point.

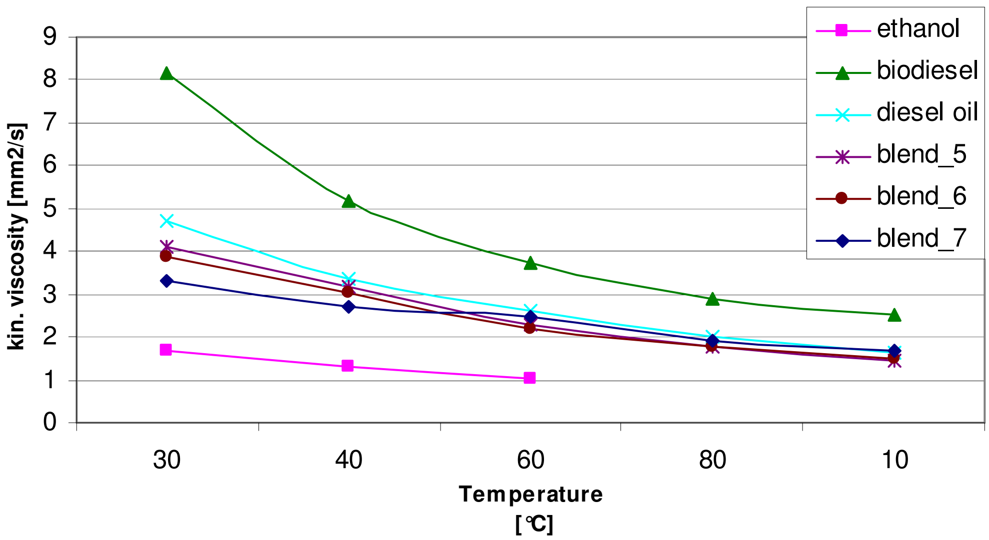

Figure 6.Viscosity results

The viscosities of the blends are same as the viscosity of the diesel oil thus the higher viscosity of the biodiesel compensate the lower viscosity of the bioethanol.

The viscosities of the fuels are decreasing with the higher temperatures. It was to expected [1,2]. The viscosity of the biodiesel drop mostly. Based on the measurements the function between the viscosity of the biodiesel and the temperature is the following (1):

$$\eta_{biodiesel} = -3{,}5746\ln(T) + 7{,}9175 \quad (1)$$

The investigated blends were stabile at normal temperature, but some of them were cloudy. These cleared off with the increasing the temperature. It means that some measurements could be done to investigate the fuel temperature effect on the injection and burning.

The investigated fuel blends met the requirements for diesel, their viscosity was between 2,15 and 3,7 mm2/s.

CONCLUSION

The researches have shown that low biofuel content (up to maximum 10% of each biocomponent) blends fulfill the diesel's lucubration requirements. The investigated blends from the lucubration viewpoint are able to introduced as biofuels.

Use of the blends could be taken out 5-15% diesel oil. It helps to stabilize the agricultural sector and creates working places.

The composition of the blend has a great influence on the blends viscosity. The viscosity of the blends can be approached with the equation (1). The blends fulfill the diesel viscosity requirements, thus the blends are ready to get installed in compression ignition engines.

Investigation the viscosity effect on the injection picture will be our next step in a special injection bench.

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