

Biodiesel Utilization Conference

Biodiesel Lubricity

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Lubricity research at MU



The primary goal: determine the concentration of biodiesel that would raise the lubricity of the new low sulfur diesel fuel (15 ppm or less).

1. Verify the chemical composition of the new 15 ppm low sulfur diesel fuel, biodiesel, and designated biodiesel blends.
2. Determine the minimum amount of biodiesel that must be added to diesel fuel that has less than 15 ppm sulfur so that diesel fuel injection systems would receive adequate lubrication.

The Reduction in Sulfur



Time	Sulfur
Prior to October 1993	5000 ppm
After October 1993	500 ppm
After June 1, 2006	15 ppm

Why does the EPA feel we must lower the sulfur content in petroleum diesel fuel?

- Anticipate 90% reduction in exhaust emissions (EPA estimates)
- Catalytic converters last longer
- Lower HC emissions
- Lower NOx emissions
- Drawback? **Hydrotreating lowered the lubricity of the petroleum diesel fuel.**

Lubricity - a textbook definition:

- **Lubricity** is the ability of a liquid to provide hydrodynamic and / or boundary lubrication to prevent wear between moving parts (Anon., 2002d)
- **Lubricity** is the "quality that prevents wear when two moving metal parts come in contact with each other," (LePera, 2002)

Early research on DF lubricity

- Researchers felt it was related to fuel viscosity
- Later, lubricity research suggested that natural lubricity of DF was attributed to:
 - Sulfur
 - Oxygen
 - Nitrogen
- The most recent lubricity research has removed sulfur from this list.

Impact of low Lubricity diesel fuels...

- Rotary distributor injection system failures (LePera, 2000).
- This pump design relies almost entirely on DF for lubrication.



Three Ways to evaluate the Lubricity of a fuel

1. Vehicle Test
 - Requires extended length of time (500-1000 hr)
 - Data may not be available for a span of 1-2 years
2. Bench test
 - Requires 500-1000 hr operation
 - Data available in 1-3 months
3. Lubricity test
 - Least expensive, accurate
 - Data available in one week



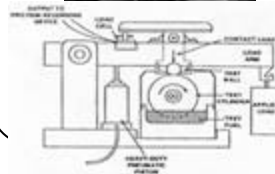
Types of Laboratory test for Lubricity.

- No standard lubricity test equipment has been selected **worldwide** as "**the test procedure**" to evaluate the lubricity of petroleum diesel fuel.
- Tests available to test lubricity:
 - SLBOCLE (scuffing load ball on cylinder lubricity evaluator)
 - ASTM D 6078-99
 - HFRR (high frequency reciprocating rig)
 - ASTM D 6079-99
 - Others

SLBOCLE Test

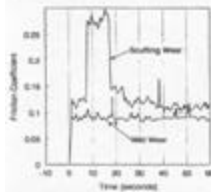


- Steel ball bearing
- Steel rotating-ring
- Immersed in the test fluid
- Weight is applied until a "scuff" mark is seen on the rotating ring
- 3100 grams without scuffing passes the SLBOCLE. (SWRI)



SLBOCLE

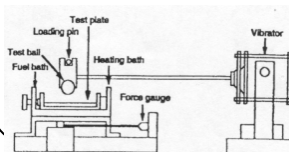
- 50 mL of fuel
- Adjusted to 25 °C (77 °F)
- 50% Relative Humidity
- 525 rpm (the ring speed)
- 500g mass applied
- Tangential force recorded
- High Friction coefficient = scuffing
- Single (6000g) vs. Incremental loading



HFRR Test



- The HFRR test is a computer controlled reciprocating friction and wear test system.
- A steel ball
- Reciprocated (1mm)
- 50 hertz
- 200g load
- 75 min.
- **Developed in England.**



HFRR



- 2 mL of Fuel
- Adjust to 25 °C or 60 °C (77 °F or 140 °F)
 - 60°C preferred
- Non-rotating ball lowered
 - 200g mass
- Ball contacts test disk (in fuel)
- 1 mm stroke @ 50 hertz
- 75 min
- Wear scar measured under 100x

Fuel blending

- Biodiesel Fuel was provided by Ag Environmental Products, Omaha, Nebraska.



- 15 ppm #1 Diesel and #2 Diesel (Tier 2 2004) Fuel were secured from Chevron Phillips Chemical Company, Houston, Texas.



Fuel Blending (continued)

- The fuels were weighed using an electronic scale.
 - #1 DF weighed 778.71g/l
 - #2 DF weighed 805.50g/l
 - BD weighed 850.50g/l



Computation of a One Percent Biodiesel / Diesel Fuel Blend

Fuel Type	Fuel Density	Percent of Blend	Mass needed
Diesel Fuel	805.50 g/l (6.695lb/gal)	99%	3,009.2 g (6.628 lb)
Biodiesel	850.50 g/l (7.069lb/gal)	1%	32.09 g (0.07069 lb)

**All blends were mixed using the same procedure (0.5, 1, 2, 4, and 12%).

Blends tested for lubricity

- The fuel was blended volumetrically using the following ratios:
- # 1 DF and biodiesel
 - 1% BD : 99% DF
 - 2% BD : 98% DF
 - 4% BD : 96% DF
 - 12% BD : 88% DF
- # 2 DF and biodiesel
 - .5% BD : 99.5% DF
 - 1% BD : 99% DF
 - 2% BD : 98% DF



Lubricity Testing

- Each blend sealed in a one gallon steel container and transported to Williams Laboratory in Kansas City, KS for SLBOCLE testing (ASTM D 6078-99) and fuel analysis.



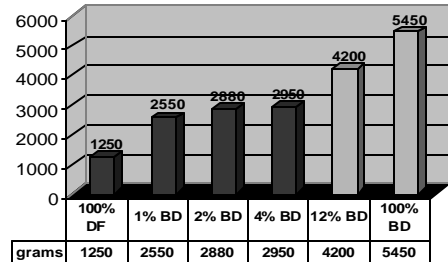
Fuel Analysis

Fuel analysis on the biodiesel used ASTM D 6751

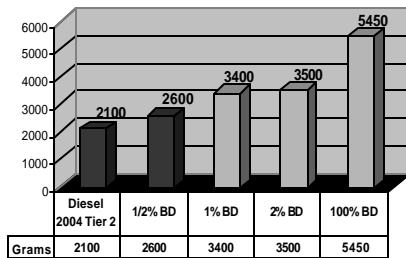


Fuel analysis on the #1 & #2 diesel fuel used ASTM D 975

SLBOCLE for #1 Diesel Fuel, Biodiesel, and Biodiesel Blends - D 6078



SLBOCLE for #2 Tier 2 2004 Diesel Fuel, Biodiesel, and Biodiesel Blends - D 6078



Conclusions

- Hydrotreating used to remove sulfur
- Hydrotreating has also removed Oxygen and Nitrogen
- Lubricity will be lower for 15 ppm diesel fuel (than 500 ppm)
- Lubricity of number one fuel will be lower than number two
- Lubricity additives will be used
- SLBOCLE and HFRR test procedures have evolved

Conclusions (con't.)

- HFRR is gaining favor over SLBOCLE – (correlated better with pump bench testing)
- In the US, the EMA prefers the SLBOCLE
- HFRR is less operator intensive and is believe to have better repeatability
- By adding as little as 1-2 % Biodiesel to #2 DF we were able to increase the lubricity of the #2 DF to a level that was safe to use in a diesel engine.

Questions / Comments?



Thank You