Lubricity Benefits

Background
All diesel fuel injection equipment has some reliance on diesel fuel as a lubricant. The lubricating properties of diesel fuel are important, especially for rotary and distributor type fuel injection pumps. In these pumps, moving parts are lubricated by the fuel itself as it moves through the pump—not by the engine oil. Other diesel fuel systems—which include unit injectors, injectors, unit pumps, and in-line pumps are partially fuel lubricated. In these systems the mechanism typically consists of a plunger or needle operating in a sleeve or bore, where the fuel is used to lubricate the walls between the reciprocating piece and its container. The lubricity of the fuel is an indication of the amount of wear or scarring that occurs between two metal parts covered with the fuel as they come in contact with each other. Low lubricity fuel may cause high wear and scarring and high lubricity fuel may provide reduced wear and longer component life.

Lubricity has sometimes been mistakenly compared to the viscosity, or thickness of a fuel. The following statement from Lucas[1] (the leading fuel injection equipment manufacturer in England, that was recently purchased by Delphi) explains it well:

“The lubrication of the fuel is not directly provided by the viscosity of the fuel, but by other components in the fuel which prevent wear on contacting metal surfaces.”

For many years, the lubricity of diesel fuel was sufficient to provide the protection needed to maintain adequate performance. Recent changes (1993 and beyond) in the composition of diesel fuel, primarily the need to reduce fuel sulfur and aromatic levels, and the common chemical process used to accomplish these changes (called hydro-treating) have inadvertently caused the removal of some of the compounds that provide lubricity to the fuel. According to Mr. Paul Henderson, Quality Management Systems Manager for Stanadyne Automotive Corp. (the leading independent US manufacturer of diesel fuel injection equipment) in comments provided to the Chairman of the Kansas House Environment Committee March 8, 2000:

“There have been numerous examples from the field where lack of lubricity in the fuel has caused premature equipment breakdowns and in some cases, catastrophic failures. This problem will be more dramatic as EPA moves to further reduce the sulfur levels in petrodiesel fuel.”

The lubricity of diesel fuel can vary dramatically. It is dependent on a wide variety of factors, which include the crude oil source from which the fuel was produced, the refining processes used to produce the fuel, how the fuel has been handled throughout the distribution chain, and the inclusion of lubricity enhancing additives whether alone or in a package with other performance enhancing additives. Typically, Number 1 diesel fuel (commonly referred to as kerosene), which is used in colder climates, has poorer lubricity than Number 2 diesel fuel.

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A 1998 review paper on fuel lubricity worldwide[2] showed that diesel fuel in the US and Canada is some of the poorest lubricity fuel found in the entire world (see Figure 1 attached). Of the 27 countries surveyed, only Canada, Switzerland, Poland and Taiwan had poorer lubricity fuel than the US. With a mean fuel lubricity of just under the recommended specification of an HFRR wear scar diameter of 460 microns, fully 50% of the US fuel was found to be above that recommended by equipment manufacturers.

These US data are with diesel fuel refined to meet the current EPA restriction of 500 ppm maximum sulfur specification. The severe hyrdrotreating required to reduce fuel sulfur to the new EPA 2006 specification of 15 ppm sulfur maximum will cause a further reduction in fuel lubricity compared to today's diesel fuel, and is of concern to engine and fuel injection equipment manufacturers.

Lubricity Benefits Provided by Biodiesel
The addition of biodiesel, even in very small quantities, has been shown to provide increases in fuel lubricity using a variety of bench scale test methods. A diagram of the various testing apparatus can be seen in chart provided by Lucas (attached). The two most popular bench test methods for lubricity are the Ball on Cylinder Lubricity Evaluator (BOCLE), and the High Frequency Reciprocating Rig (HFRR). The BOCLE is commonly used to evaluate the lubricity of fuels or fuel blends but does a poor job of characterizing the lubricity of fuels containing lubricity additives, while the HFRR is commonly used for both the neat fuels and with fuels containing small amounts of lubricity enhancing additives.

The Fuel Injection Equipment (FIE) manufacturers have adopted the use of the HFRR (ISO 12156-2:1998), and recommend that all diesel fuel meet a limit of 460 micron maximum Wear Scar Diameter (WSD)[3]. For the HFRR, a lower wear scar indicates better lubricity.

Biodiesel has been tested, at varying concentrations, with poor lubricity Number 2 and Number 1 diesel fuels representative of that on the market after 1993 (i.e. fuel refined to meet a 500 ppm maximum sulfur content). The results are illustrated in the table on the next page.

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Percent Biodiesel	HFRR Scar (microns)*	
	Number 2	Number 1
0.0	536	671
0.4	481	649
1.0	321	500
2.0	322	355
20.0	314	318
100.0	314	314

*Results provided by Stanadyne Automotive Corp.

For the Number 2 diesel fuel, 1% biodiesel was sufficient to achieve the desired increase in lubricity, while the Number 1 diesel fuel took almost 2%. In addition, the data show that most of the lubricity benefits of the biodiesel were achieved by adding only 2% biodiesel to either Number 1 or Number 2 diesel.

Based on the HFRR testing run by Stanadyne, and testing from other laboratories showing similar results, Stanadyne Automotive has stated:

"….we have tested biodiesel at Stanadyne and results indicate that the inclusion of 2% biodiesel into any conventional diesel fuel will be sufficient to address the lubricity concerns that we have with these existing diesel fuels. From our standpoint, inclusion of biodiesel is desirable for two reasons. First it would eliminate the inherent variability associated with the use of other additives and whether sufficient additive was used to make the fuel fully lubricious. Second, we consider biodiesel a fuel or fuel component—not an additive…Thus if more biodiesel is added than required to increase lubricity, there will not be the adverse consequences that might be seen if other lubricity additives are dosed at too high a rate."

The reasoning behind Stanadyne's support of 2% biodiesel makes biodiesel an ideal solution to the existing lubricity problem with diesel fuel—while supporting other environmental, energy security, and economic development initiatives. As EPA forces the further removal of sulfur from diesel fuel in 2006, which will undoubtedly worsen fuel lubricity, the concentration of biodiesel can be raised to that necessary to fully protect this future fuel as well.

Additional lubricity testing has been performed on biodiesel at Southwest Research Institute[4] (see figure 11 attached) using an updated BOCLE apparatus (Scuffing Load BOCLE), on CARB fuel, EPA fuel, as well as Jet A-1 fuel. Jet A-1 fuel is similar to Number 1 diesel fuel or kerosene. For the Scuffing Load BOCLE, a higher load capacity indicates better lubricity, and the recommended specification is 3000 grams load capacity minimum.

These test results also showed a significant improvement in lubricity when adding biodiesel to all three of these fuels, although the EPA and CARB fuel chosen for these tests were already above the required lubricity level. In fact, biodiesel tested higher in lubricity than any other diesel fuel tested at the Institute. The conclusions drawn by the researchers from Southwest Research Institute were:

“Biodiesel fuels consisting of methyl esters of soybean oil had excellent scuffing and adhesive wear resistance that exceeds those of the best conventional diesel fuels.”