

Impact of Biodiesel on Lubricant Corrosion Performance

Katherine M. Richard
Infineum USA, L.P.

Stuart McTavish
Infineum UK, Ltd.

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ABSTRACT

The global use of biodiesel fuel blends derived from fatty acid methyl esters (FAME) is increasing; driven by legislation derived from political, economic and environmental factors. The presence of FAME biodiesel changes the operating environment of the engine and after treatment devices, affecting the performance characteristics and requirements of the lubricant. As part of a wider research project into the impact of biologically-sourced fuels on crankcase lubricant performance, this paper documents the impact of biodiesel on corrosion-related performance. The effect of FAME biodiesel on lubricant corrosion control and the differences in performance due to FAME source are described. Mechanistic studies into the corrosive nature of FAME are reported. Novel lubricant technologies tailored to control the negative impact of FAME in the crankcase are demonstrated.

INTRODUCTION

The use of biodiesel as a diesel fuel extender or alternative fuel has been growing rapidly due to global interest in renewable energy sources. Biodiesel consists of fatty acid methyl esters (FAME) that are made by the transesterification of vegetable oils or animal fats. Organizations such as ASTM and ISO have adapted fuel specifications to account for the use of biodiesel blends. In Europe, standard diesel fuel (EN 590) may contain up to 7% FAME, designated as B7, as of October 2009. ASTM D975 allows the use of up to B5. This FAME content has been determined to not require changes in engine hardware for efficient operation. ASTM D7467

covers B6 to B20 blends, but engine manufacturer guidelines vary on the use of these blends. In the United States, fleets commonly employ B20 as this fuel qualifies fleets for compliance under the Energy Policy Act of 1992.¹

The impact of FAME on lubricant performance has been studied for many years.^{2,3,4} Biodiesel has known compatibility issues with certain materials⁵, although the impact is considered to be lower for B20 and below. The main concerns arise from the consequences of fuel dilution, as the higher boiling point range of FAME relative to petroleum diesel causes FAME to accumulate in the sump.

Modern engines equipped with diesel particulate filters (DPF) may have in-cylinder post-injection to regenerate the filter. While several studies conducted with biodiesel did not show indications of unusual bearing wear in the used oil analysis, the observed level of fuel dilution was relatively low^{6,7,8}. In-cylinder post-injection, however, may facilitate increased levels of fuel dilution. This is due to unburned fuel reaching the cylinder walls and running down into the sump.

The frequency of regeneration cycles will be affected by the duty cycle of the vehicle. Highway driving generally results in fewer regenerations and lower fuel dilution, while city driving and high idle result in increased fuel dilution.⁹

Standard industry tests were conducted to determine the effect of FAME versus petroleum diesel on the corrosion performance of lubricants.

CORROSION BENCH TESTING

The method that was employed to measure the corrosion performance of oils, both with and without the addition of biodiesel, was the High Temperature Corrosion Bench Test (HTCBT) (ASTM D6594)¹⁰. The HTCBT method heats the oil to 135°C for 168 hours while air is bubbled through at a rate of 5 liters per hour. These conditions subject the oil to thermal and oxidative stress that may generate acidic/corrosive species in the oil. The sample tube that contains the oil also contains coupons of copper, lead, tin, and phosphor bronze. This test is static, with no mechanical wear taking place. At the end of the test, passing oils should contain no more than 20 parts per million (ppm) copper and 120 ppm lead.

COMMERCIAL OILS – Several commercially available oils meeting the ACEA E6 specification were tested with varying amounts of soy methyl ester (SME) meeting ASTM D6751 added. The quality levels of all oils evaluated are shown in Table 1.

Table 1: Commercial Oil Samples

Oil	Product Quality	Comm. Available?
A	ACEA E6, E7	Y
B	ACEA E6, E7; API CI-4	Y
C	ACEA E6, E7	Y
D	ACEA E6	Y
E	ACEA E6, E7	Y
F	ACEA E7, E9; API CJ-4	Y

Each of the oils was diluted with 10% fuel to give the finished oil SME concentrations seen in the graphs. The balance of the fuel was petroleum diesel. The values reported for 0% FAME content correspond to both neat lubricant (no fuel added) and lubricant with 10% petroleum diesel added. It has been observed that petroleum diesel does not have an impact on HTCBT performance.

The HTCBT results for copper and lead are shown in Figures 1 and 2, respectively. (Note that the y-scale of Figure 2 is twenty times that of Figure 1.) The majority of the oils, with the exception of oil D, show passing copper corrosion performance when there is no FAME present in the oil. With as little as 1% of SME in the lubricant, most of the oils display failing performance for copper dissolution in the HTCBT. The level of copper dissolution increases with SME content. However, the change in copper dissolution is greater when moving from 1% to 3% FAME concentration than from 3% to 5%.

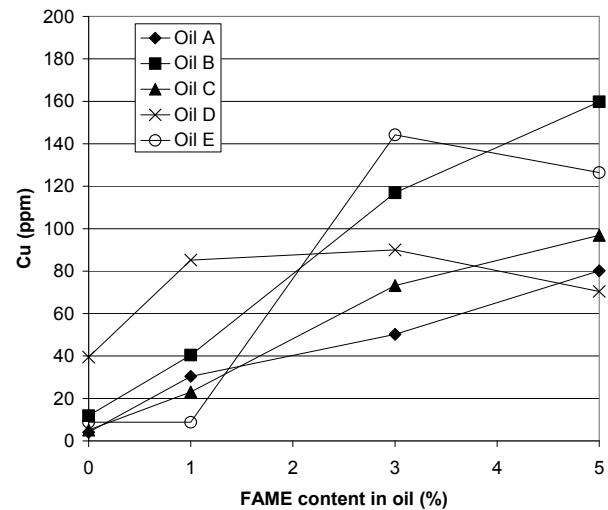


Figure 1: HTCBT copper corrosion results for commercial ACEA E6 oils diluted with SME-containing fuel.

Lead is much more susceptible to the corrosion induced by FAME. Lead corrosion appears to be exponential with FAME dilution. The presence of 5% SME in the oil results in EOT lead levels well over one thousand parts per million.

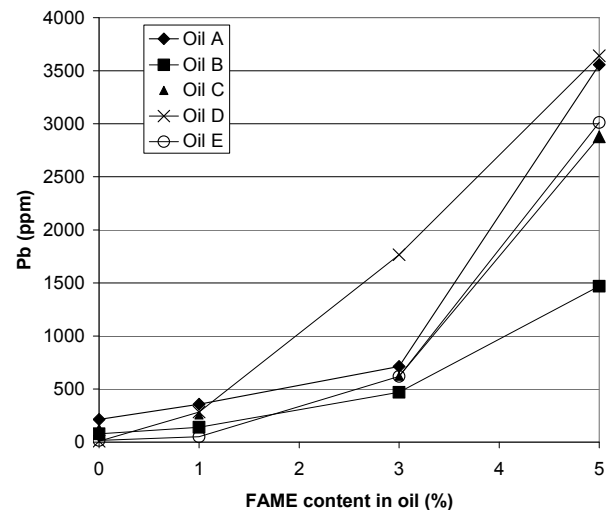


Figure 2: HTCBT lead corrosion results for commercial ACEA E6 oils diluted with SME-containing fuel.

IMPACT OF FAME SOURCE – The source of the fatty acids used to produce FAME will have an impact on the chemical structures in the fuel. FAME will typically have a mixture of chain lengths ranging from 16 to 24 carbon atoms. The carbon chain length distribution and the number of double bonds per chain vary with fatty acid source. Three common sources of FAME – palm, rapeseed, and soy – were tested to determine the impact of feedstock on corrosion. Select properties of the FAME are shown in Table 2.