Development of High Performance Heavy Duty Engine Oils

Frank Lauterwasser
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Pressures on the OEMs
Main Drivers for New HD Diesel Engine Technology

The Old Days

Performance
Reliability
Operating Costs

Today

Globalization
Performance
Fuel Economy
New Hardware, Fuel, Oils
Operating Costs
Reliability
Emissions Compliance

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Challenge of Emission Compliance

Numbers next to the corners of each square in the graphic represent NOₓ or particulates specification in g/kW-hr.

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Drivers For Increased Biodiesel Use In U.S.
Growth will no longer be based solely on relative economics

- Renewable Fuel Standard (RFS)
- State Biodiesel Mandates
- Light Duty B20 CAFÉ Credits
- Low Carbon Fuel Standard (LCFS)
Biodiesel Use Can Challenge Conventional Diesel Engine Oils

Engine deposits and lead corrosion
Fuels, Lubricants, Additives and After-treatment Changes to Achieve Heavy Duty Emissions Targets

- Engine
- Diesel Particulate Filters
- Ultra-Low Sulfur Diesel Fuel
- Lubricity and Cold Flow Additive
- Low Ash
- Heat Tolerance
- Volatility
- Low SAPs
- Oxidation Inhibitors
- Base Oil Change
- Low Sulfur
  - Fuel
  - Base Oil
  - Additive
- Low Phosphorous
  - Additive
- Urea
  - Additive
API CJ-4: Most Robust Heavy Duty Engine Oil*

- CJ-4 oils allow the use of EGR, DPF to reach the low emission compliance for 2007
- Low SAPs level to enable the use of after treatment system
  - Low ash level 1.0 for DPF protection
  - Higher stress on the oil due to EGR

2010 Emission Regulation (no new category)
- Lower NOx (SCR and EGR, or higher EGR rate)
- Particulates matters stay at the 2007 limit
- ULSD 15 ppm on and off highway
- Oil for 2010 emission regulation: CJ-4 oil low SAPs (1.0 ash limit)
  - 15W40 and 10W30 (fuel economy) available

*James A. McGeehan, Chairman of ASTM Heavy Duty Engine Oil Classification Panel
James A. McGehean et al, SAE 2009-01-1781 (DPF)
Wim van Dam et al, SAE 2009, submitted (fuel economy)
CO₂ Emissions – Regulations in U.S. Future?

Greenhouse Gas by U.S. Economic Sector

- Electricity Generation
- Agriculture
- Transportation
- Commercial
- Industry
- Residential

Source: Environmental Protection Agency

Transportation Sector CO₂ Emissions by Mode, 2005

- Heavy Trucks 62%
- Cars & Light Trucks 20%
- Air 10%
- Water 3%
- Pipeline 2%
- Off-Highway 2%
- Buses 1%

Source: Transport Topics

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Active and Pending HD Fuel Economy Regulations

- **Japan**
  - First Truck Fuel Economy Standards in the World
    - Fully Implemented in 2015
    - Based on engine dynamometer test
    - Fuel economy assessed at various operating conditions and parameters

- **United States**
    - Study in progress to establish regulations and criteria— not likely simple mpg, probably ton-miles/gallon or some other measure
    - Likely to be implemented in 2016/2017
    - CO₂ emissions regulations may be implemented earlier

- **Europe**
  - No current Truck Fuel Economy Standard, but CO₂ emissions considered when establishing NOx and Particulate Emissions limits in EURO 6
The Impact of Biodiesel Use on the Lubrication of Diesel Engines

Presented by
Frank Lauterwasser
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Authors
Maarten Boons
Walter Hartgers
Frank Lauterwasser
Michelle Morcos
Gary Parsons

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The Role of Renewables

Chevron Views

- The world needs all kinds of energy sources – Oil, gas, unconventionals and renewables – To meet growing demand in an environmentally sound manner

- Developing infrastructure to produce and distribute new forms of energy such as biofuels on a large scale will be a significant challenge

- Our goal is energy solutions that are practical, innovative and enduring
Non-Food Biofuels Technology Pathways

- Biotechnology Routes
- Catalytic Routes
- Transportation Fuels
- Thermochemical Routes
- Biomass

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Biodiesel is a Global Phenomenon

- **Argentina**
  - Soy
  - Mamouna (plant)
  - Babsoo (nut)

- **Brazil**
  - Soy
  - Palm
  - Cooking Oil

- **Canada**
  - Soy
  - Tallow
  - Fish Oil

- **United States**
  - Soy
  - Tallow
  - Cooking Oil

- **Europe**
  - Rape Seed

- **India**
  - Jatropha
  - Tallow

- **Asia**
  - Jatropha
  - Cooking Oil

- **Thailand & Malaysia**
  - Palm

- **Philippines**
  - Coconut
  - Palm

- **Indonesia**
  - Palm

- **Ecuador**
  - Palm

- **Latin America**
  - Jatropha

- **Australia/New Zealand**
  - Sheep Marrow
  - Tallow

- **Norway**
  - Fish Oil

- **United States**
  - Soy
  - Tallow
  - Cooking Oil

- **Europe**
  - Rape Seed
Biodiesel Feedstock Properties Impact Performance

- Higher Cetane
- Better Cold Flow
- Better Oxidation Stability

Source: NREL
OEM Biodiesel Issues & Concerns

**Fuel System**
- Injector deposits
- Fuel filter plugging
- Injection pump durability
- Materials incompatibility
- Fuel Instability
- Low temperature handling
- May reduce detergency and anti-foam properties of fuel additive packages

**Emissions Systems**
- Impact on after-treatment devices and sensors
- Impact on NOx emissions
- Lower BTU content and fuel economy

**Lubricant Performance**
- Fuel dilution
- Corrosion
- Viscosity change
- Oxidation
- Piston Deposits
- Crankcase Deposits
Crankcase Fuel Dilution With Biodiesel

Properties of biodiesel lead to higher levels of fuel dilution

- Higher droplet size
- Larger fuel spray droplet size

Diesel – normal droplet size

Surface Tension

Specific Gravity

Viscosity, cSt @ 100°C
Late Post-Injection Leads to Higher Levels of Fuel Dilution

- Some OEMs have reported 15-20% fuel dilution (FAME) at oil drain
- OEMs often reduce drain intervals when biodiesel is used
Crankcase Fuel Dilution With Biodiesel

Higher and Narrower boiling range of biodiesel makes it more persistent once it enters the crankcase

There is a need for a robust analytical method to measure biodiesel content in used engine oils.
Oil Dilution During Particulate Trap Regeneration

Fuel Dilution vs. Mileage

- Biodiesel
- Mineral Diesel
Biodiesel Fuel Dilution Measurement By GC-FID

- Accurate fuel dilution measurement is important for R&D

GC-FID Measurement is Confounded in Used Oil

Michelle Morcos et al., SAE 2009 submitted
Results From OEM Field Test Samples

Biofuel Dilution for Vehicle Running on B20 SME

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Cummins High Temperature Corrosion Bench Test

API / ACEA / Cummins Require HTCBT ASTM D6594 for Heavy Duty Diesel Oils

High Temperature Corrosion Bench Test
- Air bubbling at 10 l/h through 150 ml sample
- No Catalyst
- Temperature 135°C
- 4 metal strips are submerged
  - Copper
  - Lead
  - Tin
  - Phosphor Bronze
- Duration 168h
- EOT oil samples checked for
  - Cu, Pb and Sn Increase
- Copper Strip Rating at EOT
Lubrication Aspects – Corrosion

B100 Fuel Dilution
Impact on Lead and Copper Corrosion

20 wt% B100 dilution gives 9000 mg Pb

Used oil Pb
Reference with 6 wt% diesel fuel

Used oil Cu
API CJ-4 pass limit on HT-CBT

HT-CBT Pb & Cu numbers (ppm)

Wt % B100 in Lubricant

0 5 10 15 20 25

0 100 200 300 400 500 600 700 800 900 1000

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Mack T-12 Standard Engine Test

Mack T-12 is a 300-hr test run in Mack E-7E-tech 460-HP engine with high EGR

Test is part of API CJ-4, as well as Mack EO-O specification

- First 100 hr are at rated speed and power
- Last 200 hr are over-fueled at peak torque to maximize wear rates

Primary purpose is evaluation of oxidation, Pb corrosion, and liner and ring wear resistance
Oil Oxidation and Lead Corrosion Identified With Biodiesel Blend Use

Rapid rise in lead corrosion with SME B20


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Mack T-12 Parameter Comparison
API CJ-4 Heavy Duty Engine Oil

- ULSD
- B20 = Soy

OIL
- Ring Weight Loss
- Cylinder Liner Wear
- Lead
- Lead 2

Better

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Biodiesel Blend Engine Oil Formulation Performance

![Bar chart showing Total Mack Merits for Core Lubricant (CH-4) and Biodiesel Formulation, with Core Lubricant (CH-4) having a score of 1439 and Biodiesel Formulation having a score of 1394.]

Excellent Mack T12 Pass on B20 Palm Methyl Ester
Summary

- FAME biodiesel will likely remain a part of the global diesel pool for the coming years
  - Mandates, energy independence, supports local agriculture
  - Low capital investment, low complexity plants
  - New FAME technology being developed

- Use of biodiesel can lead to lubrication issues
  - High and persistent fuel dilution
  - Oil oxidation and bearing corrosion
  - Piston deposits

- Specific methods were developed for biodiesel fuel dilution method

- Specially formulated lubricants can enable safe biodiesel use
  - An Oronite additive booster is available