Evaluation of Low Viscosity Engine Oil Wear Effects and Performance in Heavy Duty Engines Fleet Test

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Introduction

Why to reduce fuel consumption in Heavy Duty commercial vehicles?

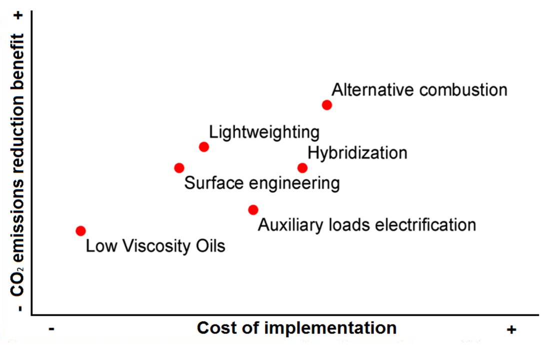
Global warming due GHG emissions.
+
Oil depletion
→ New stringent fuel economy/CO_2 standards.

Country/ region	Regulation	Current legislation
Japan	Fuel economy	2015
United States	GHG/Fuel efficiency	mandatory on 2016
European Union	CO_2 test	-
Canada	GHG	standard proposal on 2012
California	End user requirements	baseline will take place on 2015 and 2017

How to meet these severe standards for Heavy Duty commercial vehicles?

Vehicle solutions
- Aerodynamics
- Tire rolling resistance
- Idle reduction
- Intelligent driving technologies

ICE efficiency improvement
- Alternative combustion.
- Auxiliary loads electrification
- Hybridization
- Reduce Engine friction



Low Viscosity Oils

Fuel consumption
- → Lower film thickness
- → Lower hydrodynamic friction.
- → Lower mechanical losses in lubricated pairs
- → Reduced fuel consumption

Engine wear/Oil performance
- → Lower film thickness
- ? Increasing wear rates
- ? More accelerated oil degradation
- ? Increase of maintenance actions
- ? Reduction of expected engine life

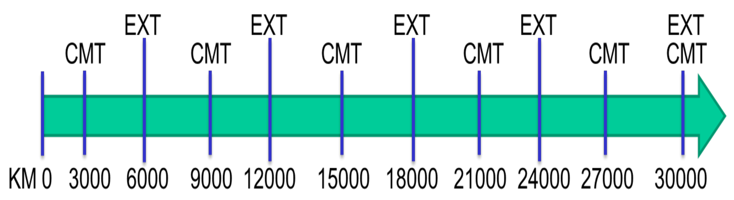
Objectives

- To assess the effects on wear engine rate and its potential impact on engine life.
- To study oil performance and wear phenomena by means of a complete oil analysis program for a thorough control of oil during ODI.

Design of experiment

Fleet test: 39 urban buses

- 20 CNG EEV: 10 Candidates, 10 references
- 9 Diesel Euro IV (Diesel I): 4 Candidates, 5 References
- 10 Diesel Euro V (Diesel II): 5 Candidates, 5 References



ENGINE OILS	OIL A	OIL B	OIL C	OIL D
Type	Baseline Diesel I engine Oil	Baseline Diesel II /CNG engine Oil (LS)	Low viscosity candidate Diesel I & II engine Oil	Low viscosity candidate CNG engine Oil (LS)
SAE grade	15W40	10W40	5W30	5W30
Density@15ºC [g/cm³]	0.887	0.859	0.861	0.855
Viscosity@40ºC [cSt]	108	96	71	68
Viscosity@100ºC [cSt]	14.5	14.4	11.75	11.7
Viscosity Index [-]	>141	>145	>158	<169
HTHS Viscosity @150ºC [cP]	4.082	3.853	3.594	3.577
TBN [mgKOH/g]	10	10	16	10
API Base Oil	API G-I	API G-III	API G-III + G-IV	API G-III + G-IV
ACEA Oil Sequence	ACEA E7/E5	ACEA E6/E4	ACEA E6/E7/E9	ACEA E7/E4

	Engine Diesel I	Engine Diesel II	Engine CNG
Technology	Diesel	Diesel	CNG
Year	2008	2010	2007
Engine displacement [cm³]	11967	7200	11967
Emissions standard	EURO IV	EURO V	EEV
Number of cylinders	6	6	6
Max. effective power [kW]	220@2200 rpm	210@2100 rpm	180@2200 rpm
Max. effective torque [Nm]	1600@1100rpm	1100@1100 rpm	880@1000 rpm
Crankcase volume [l]	31	29	33
bmep [bar]	16,8@1100rpm	19,55@1100rpm	9,24@1000rpm
Thermal loading* [W/mm2]	2,85	3,97	2,33
Valve train configuration	*OHV Roller follower (hardened steel)*	*OHV Cam follower (steel)*	*OHV Cam follower (steel)*

Parameter	Technique / Instrument	Standard
Kinematic viscosity @40ºC & @100ºC	Capillary viscometer	ASTM D-445
Dynamic viscosity HTHS	HTHS Viscometer	ASTM D-5481
Wear metals and additives	ICP-OES Spectrometer	ASTM D-5185
TAN	Automatic potentiometric titrator	ASTM D-664
TBN		ASTM D-2896
Oxidation	FT-IR Spectrometer	CMT-0080-11
Nitration		CMT-0081-11
Antiwear additives		CMT-0120-12
Soot		ASTM E-2412
Glycol		ASTM E-2412
Water Content	Karl-Fischer Titration	ASTM D-6304

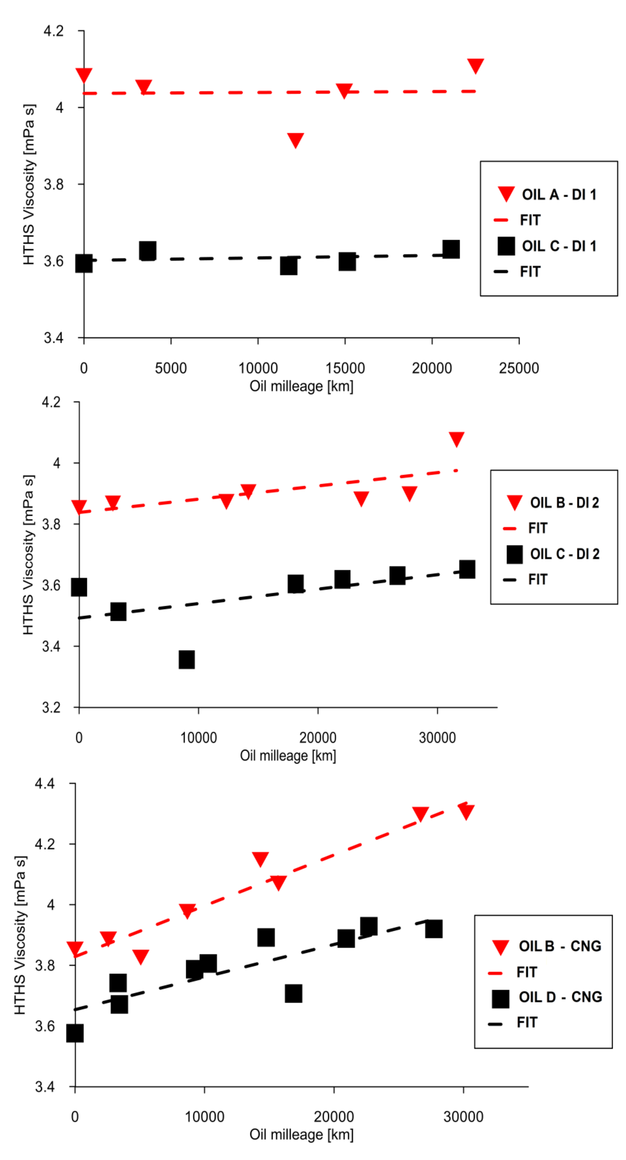
Degradation · Contamination · Wear

V. Macián, B. Tormos, Y. A. Gómez & J. M. Salavert (2012): Proposal of an FTIR Methodology to Monitor Oxidation Level in Used Engine Oils: Effects of Thermal Degradation and Fuel Dilution, Tribology Transactions, 55:6, 872-882

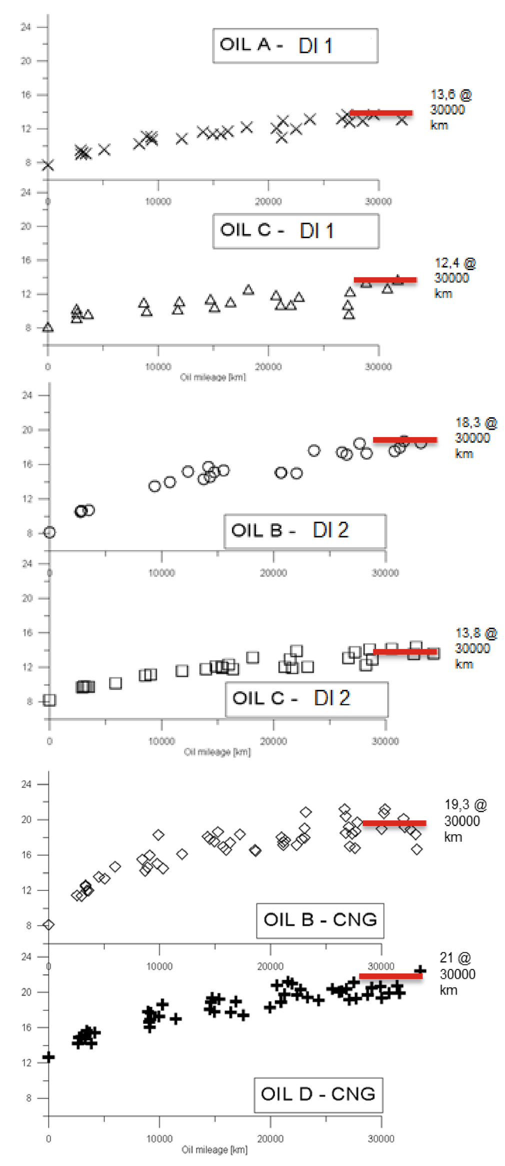
Results and conclusions

All oils have successfully completed >30000 km cycle and showed no critical malfunction.

HTHS viscosity: No significant variation.



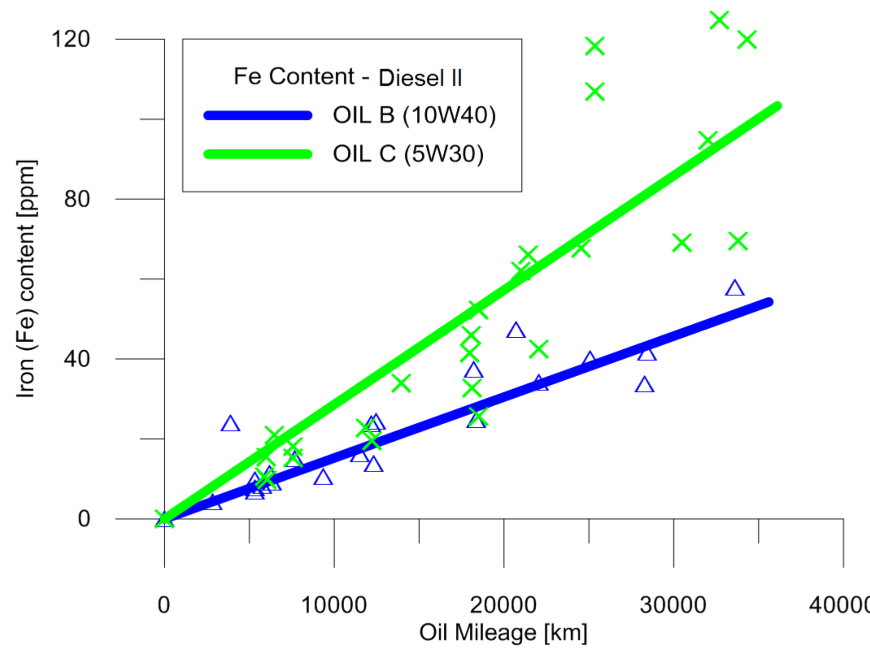
Oxidation by FTIR [Abs·cm-1 / 0.1 mm]

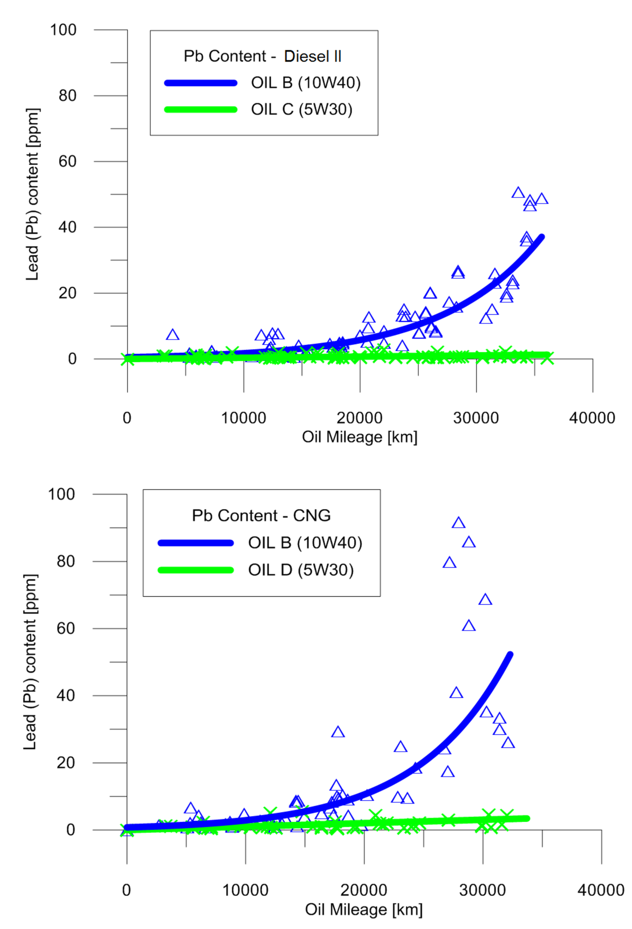


Oil oxidation rate relay both on engine technology and oil quality.

Oil	Engine technology	kV@100_init. [cSt]	kV@100_final [cSt]	%var
OIL A (14,5 cSt)	EURO IV	14,51	12,75	-12,1%
OIL C (11,75 cSt)	EURO IV	12,45	11,05	-11,2%
OIL B (14,4 cSt)	EURO V	13,34	13,09	-1,9%
OIL C (11,75 cSt)	EURO V	12,45	11,98	-3,8%
OIL B (14,4 cSt)	GNC	13,34	14,38	7,8%
OIL D (11,7 cSt)	GNC	11,83	12,95	9,5%

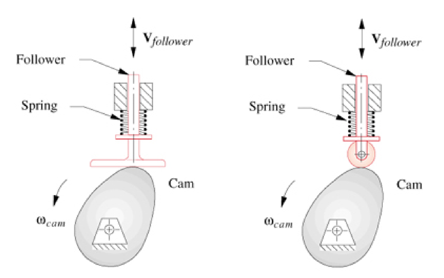
Oil	Engine technology	Wear rate **Fe** [ppm@30000 km]	Wear rate **Cu** [ppm@30000 km]	Wear rate **Pb** [ppm@30000 km]
OIL A	EURO IV	20	15	4
OIL C	EURO IV	20	10	4
OIL B	EURO V	50	10	15
OIL C	EURO V	140	5	4
OIL B	GNC	15	5	50
OIL D	GNC	10	5	4





Wear rates divergences:

- **Fe in Diesel II engines. Hypothesis: wear rate acceleration by higher thermomechanical stress. Also, different valve train configuration.**
- **Corrosive wear: Low viscosity oils = Improved formulations → Better performance**



Engine end-user should know the derived effects that LVO can imply.

These effects are engine-design dependent → A previous assessment must be done to assure engine-oil viscosity optimum combination.