BIZOL

Fuel Economy Engine Oils:

Scientific Rationale and Controversies

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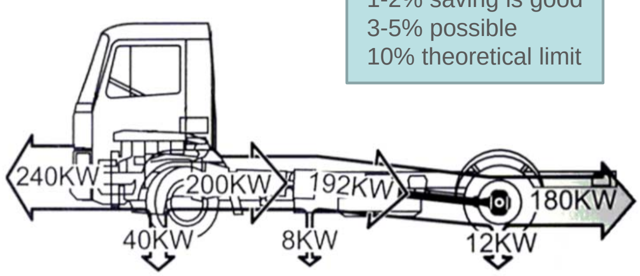
Technischer Leiter

Energy Saving Lubricant: What Is It?



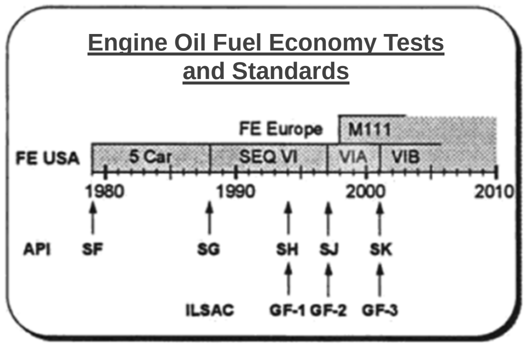
1-2% saving is good
3-5% possible
10% theoretical limit

- ✓ Thermal losses
- ✓ Friction losses in the powertrain
- ✓ Losses due to aerodynamic resistance, rolling friction, acceleration/braking cycles, etc

Sequence VID
ASTM D 7589

Uses 2009 3.6 L GM V6 and 20W30 “baseline” oil to measure the effects of automotive engine oils on the fuel economy of passenger cars and light-duty trucks equipped with a “low-friction” engine.

Recourse to History

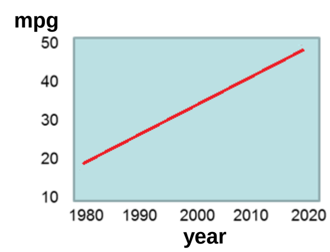


Source: Tribology for Energy Conservation, D. Dowson, Ed., Elsevier, 1998.

Fuel Economy Factors

The average fuel consumption in passenger cars has dropped from 10 L/100 km (23.5 mpg) in the 1980s to 5L/100 km (47 mpg) nowadays, moving towards the US EPA target of 56 mpg by 2025)

- ✓ **Powertrain optimisation**
- ✓ **Curb weight reduction**
- ✓ **Use of low-viscosity oils**
- ✓ **Use of coatings**

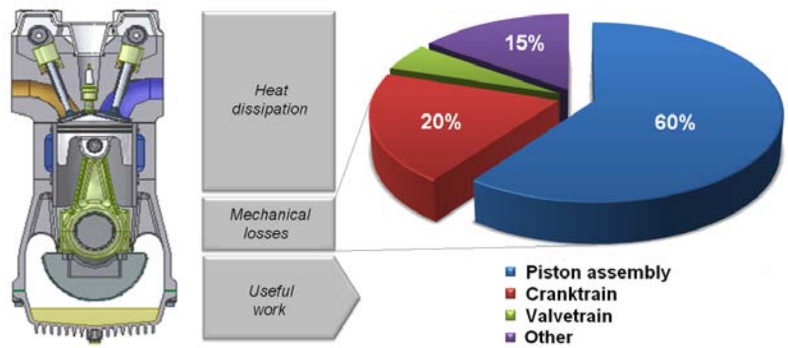


Volvo V70 1997 (170 hp)
15.2 - 7.9 - 10,6 L/100 km

Volvo V70 2006 (170 hp)
12.6 - 7.2 - 9.2 L/100 km

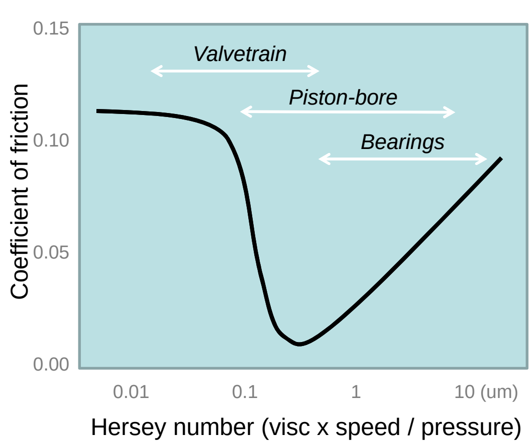
Volvo V70 2015 (180 hk)
9.0 - 5.5 - 6.8 L/100 km

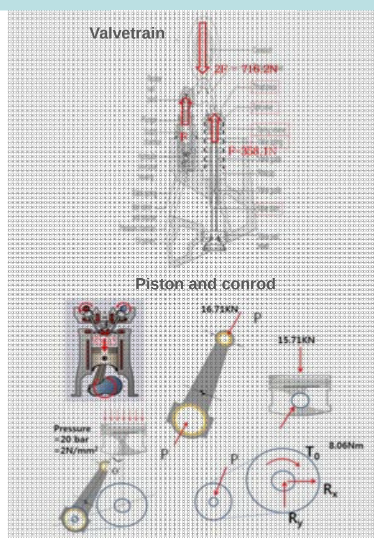
Energy Losses in the Engine



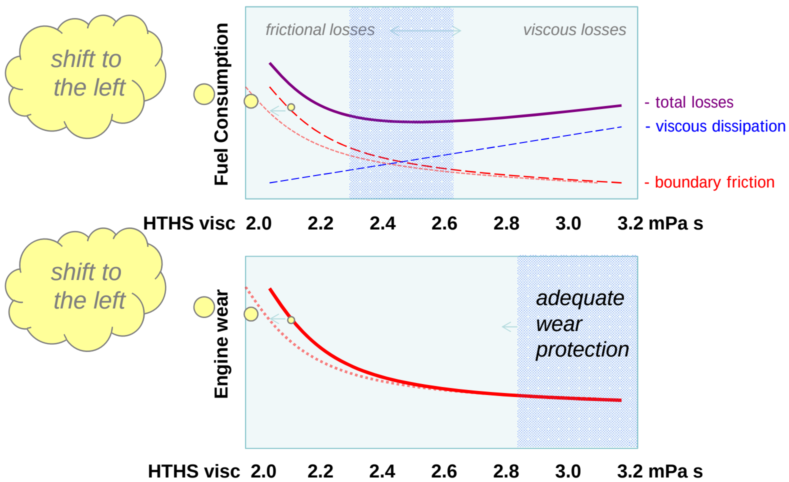
Mechanical losses: 90% viscous dissipation and 10% boundary friction.

Typical Stresses and Lubrication Regimes



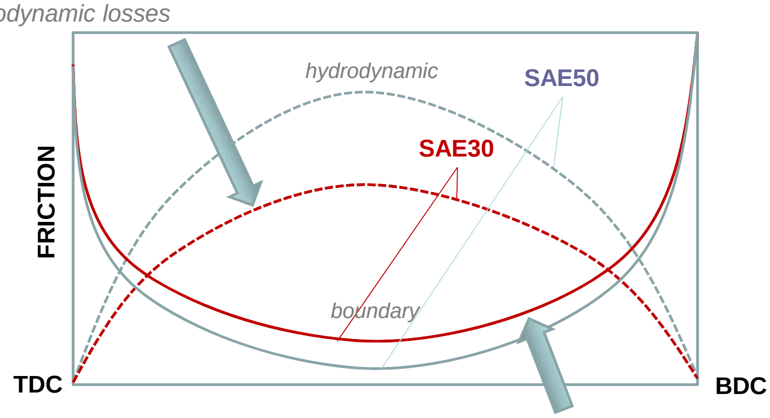


Fuel Economy from Tribological Refinement



So, Here Is Our Action Plan…

Use lower viscosity to minimize hydrodynamic losses



Use boundary lubricity additives to control wear & boundary friction

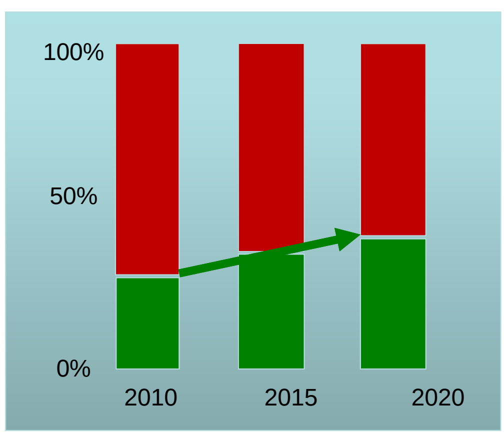
HTHS Viscosity Limits

SAE J300 - Revised January 2015

SAE Viscosity Grade	Low Temp. Cranking (cP)	Low Temp. Pumping (cP)	Minimum Kinematic (cSt)	Maximum Kinematic (cSt)	Hi-Temp. Hi-Shear (cP)
0W	6,200 @ -35°C	60,000 @ -40°C	3.8	-	-
5W	6,600 @ -30°C	60,000 @ -35°C	3.8	-	-
10W	7,000 @ -25°C	60,000 @ -30°C	4.1	-	-
15W	7,000 @ -20°C	60,000 @ -25°C	5.6	-	-
20W	9,500 @ -15°C	60,000 @ -20°C	5.6	-	-
25W	13,000 @ -10°C	60,000 @ -15°C	9.3	-	-
8	-	-	4	<6.1	1.7
12	-	-	5	<7.1	2.0
16	-	-	6.1	<8.2	2.3
20	-	-	6.9	<9.3	2.6
30	-	-	9.3	<12.5	2.9
40	-	-	12.5	<16.3	3.5 (0W-40, 5W-40, 10W-40)
40	-	-	12.5	<16.3	3.7 (15W-40, 20W-40, 25W-40, 40 monogrado)
50	-	-	16.3	<21.9	3.7
60	-	-	21.9	<26.1	3.7

Twofold reduction in HTHS!

"Oil Thinning" Gains Momentum



xxW-40, xxW-50
(HTHS 3.7-4.3 cP)

xxW-20, xxW-30
(HTHS 2.6-3.3 cP)

Upsides of Oil Thinning

Fuel economy:

Twofold reduction in viscosity => Twofold reduction in viscous losses => 5% FEI

Energy dissipation ~ viscosity × (velocity gradient)^2 × volume
$[N\ m^{-2}\ s] \times [s^{-2}] \times m^3$
$= N\ m\ s^{-1} = J\ s^{-1}$

By the way, what's about tighter piston to cylinder clearances?

Higher base oil quality

SAE 20 and lighter grades require fully synthetic base oils

Faster oil drain during service

SAE 30 drains approximately twice faster than SAE 50

Downsides of Oil Thinning

Wear

Twofold reduction in HTHS viscosity => twice thinner oil film

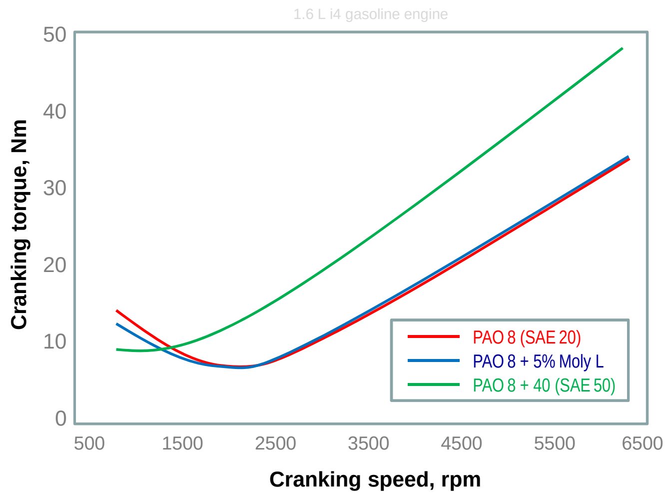
Jon Vilardo, PCMO Product Manager, Lubrizol:
"*Lower can have a negative impact on durability; the protective oil film is less robust, or under the most extreme loading conditions, non-existent*."

Simon Tung, Global OEM Technology Manager, Vanderbilt:
"*Lower viscosity grade oil might not be able to have enough oil film thickness to protect engine wear as higher viscosity grade oils*."

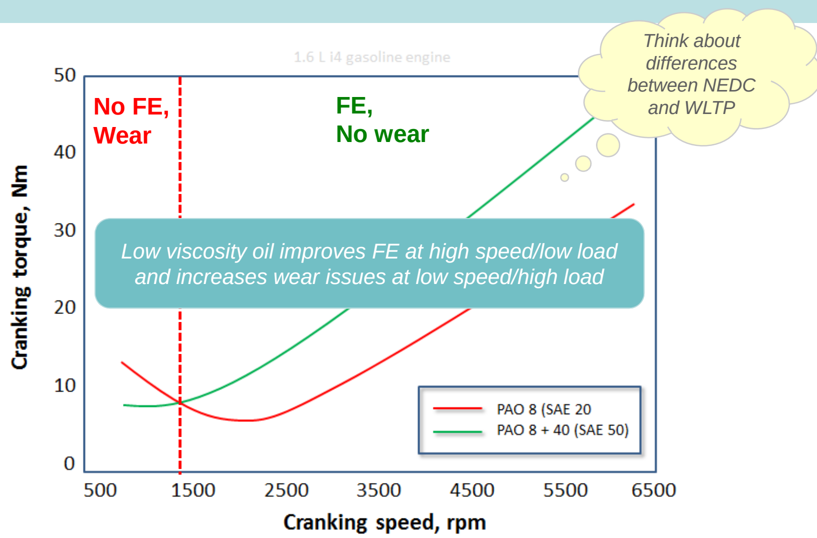
Infineum:
"*Misapplication will be a concern for OEMs, particularly the potential for new lower viscosity grades to find their way into <u>engines not designed to take advantage of the fuel economy improvements</u>*."

… and hence risking to be screwed up!

Things May Get Complicated



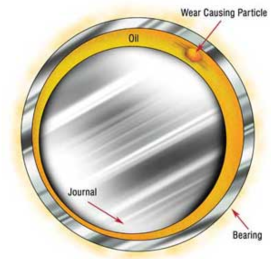
Fuel Economy vs Engine Protection



Oil Film Strength Is at Risk

Reality:
- Engine are downsized and booster for FE sake
- Start-stop is going mainstream for FE sake
- Oils are getting thinner for fuel-economy sake

Unfortunate consequence:
- Durability is put at risk for FE sake



Thinner oil is a risk in the low-speed and high-load limit and can fail to provide an adequate wear protection

Some Data to Share

Model Oil 1
SAE 0W-16

Yubase 4…. 39%
PAO 4…….. 10%
PAO 5 ……. 30%
AN 5 ……… 10%
PPD ……….. 1%
PV1016 ….. 10%

V100 = 7.8 cSt
V40 = 42.7 cSt
VI = 155
HTHS = 2.5 cP

Model Oil 2
SAE 5W-40

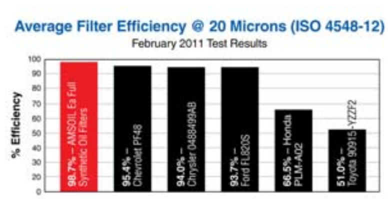
Yubase 4…. 20%
Yubase 6…. 19%
PAO 6…….. 30%
AN 5 ……… 10%
OCP ……… 10%
PPD ……….. 1%
PV1016 ….. 10%

V100 = 14.5 cSt
V40 = 89.1 cSt
VI = 170
HTHS = 4.0 cP

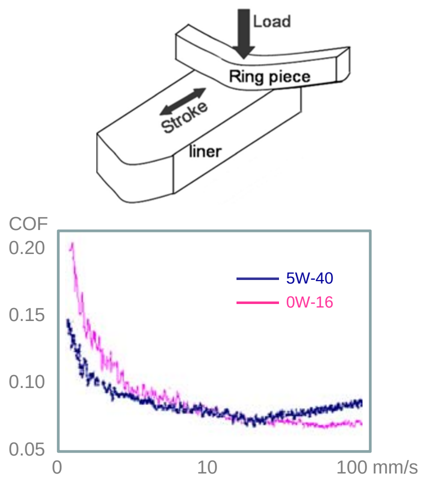
"Dirty oil" wear test

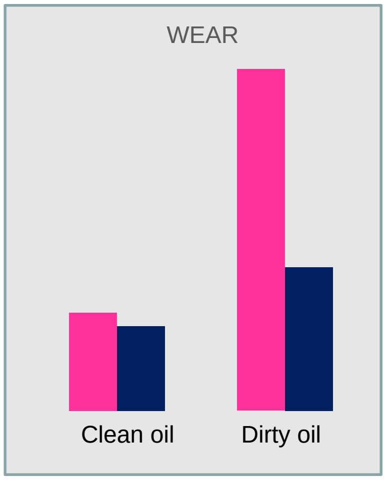
Added 0.1% quartz 10 um powder
0.1% Si_3N_4 4 um powder

Engine oil filter cutoff 20-40 um



Reciprocating Friction and Wear Test





Engine Trend: Downsize and Charge

Volvo XC90 2005 V8
4.4 L V8, 315 hp, 440 Nm

BMEP = 12.6 bar

- **Fewer cylinders**
- **Smaller displacement**
- **Same power**

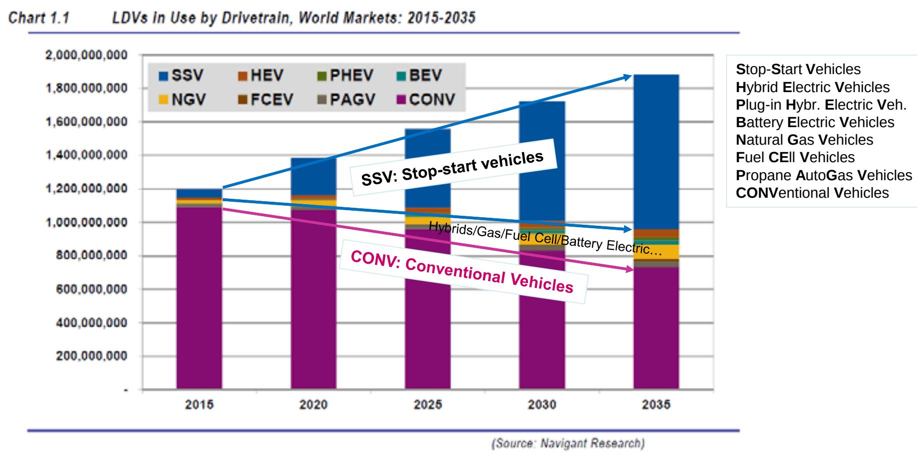
Volvo XC90 2016 T6
i4, 2.0 L, 316 hp, 400 Nm

BMEP = 25.5 bar

Consumer vehicles closing the gap with racing cars

Koenigsegg Agera 5.0 L bi-turbo, 1000 hp, 1100 Nm
BMEP = 28 bar

Engine Trend: Start-Stop



Bearings will have withstand 300,000 instead of 30,000 start-stops

Recipe for Trouble

Downsized boosting | **Start-stop** | **Thin oil**

COMPONENT WEAR

Have you ever tried “dirty oil” in the following tests?

- Bearing weight loss (Sequence VIII, ASTM D6709)
- Cam wear (Sequence IVA, ASTM D6891)
- Top ring wear (Cummins ISM, ASTM D7468)
- Cam, tappet, crosshead (Cummins ISB, ASTM D7484)
- Roller follower wear (ASTM D 5966)

OEM Recommended Crankcase Lubricants

ACEA A5/B5 SAE **0W-30**
12 cSt at 100C

Improving FE by introducing low viscosity oil

VCC RBS0-2AE SAE **0W-20**
9 cSt at 100C

Wear will become an issue

Valvoline VR1 Racing SAE **5W-50**
18 cSt at 100C

Weighing Pros against Cons

How much do I save by changing from 5W-40 to 0W-30?

$FE \propto \Delta FMEP / IMEP \propto \Delta\, HTHS / HTHS \approx 0.1 \times (3.7 - 3.0)/3.7 = 2.5\%$

I drive 30,000 km per year and consume 10 L/100 km => 3,000 L => 4,500 EUR

2.5% will save me ca **100 EUR per year!**

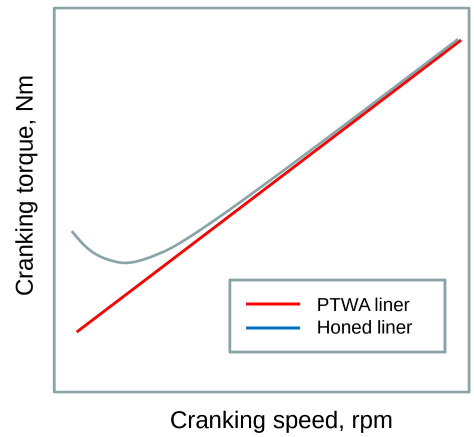
Any major engine overhaul outside of warranty period costs multiple of 1,000 EUR

Role of Cylinder Bore Coatings

Thermally sprayed coatings:
PTWA (Plasma Transferred Wire Arc) by Ford and Flame Spray Industries.
LDS (Lichtbogendrahtspritzen) by Daimler Chrysler.
APS (Atmospheric Plasma Spray), eg SUMEBore by Oerlikon Metco, etc.

Benefits:
- High porosity (possible to achieve R_{vk} upto 10 um with R_{pk} below 0.1 um)
- High thermal conductivity (efficient cooling, thicker lubricant films)

Thermally sprayed cylinder bores maintain full-film lubrication regime!



Different Engines – Different Oils

Engine 1:

- Ductile cast iron cylinder bores,
- Direct-acting mechanical bucket tappet (DAMB) valvetrain

Caution with using low viscosity oils is recommended
Significant benefit from EP/AW additives and friction modifiers.

Engine 2:

- PTWA/LDS/APS or Alusil cylender bores,
- RFF, RRA, or EMV valvetrain

Safe to use low viscosity oils
Little benefit from EP/AW additives and friction modifiers.

THANK YOU!


BIZOL
Made in Germany
reddot award 2014
winner
G
GREEN OIL
5W-30
A
ALLROUND
5W-30
T
TECHNOLOGY
5W-30
P
PROTECT
0W-40