OilDoc Conference & Exhibition
Lubricants
Maintenance
Tribology
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Towards Improving Fuel Economy through Tribology Testing

Dr Richard Baker
PCS Instruments, London, United Kingdom
Dr Clive Hamer
PCS Instruments, London, United Kingdom

Talk Outline

- **Overview of PCS**
- History of Fuel Economy
- Global Passenger Car Growth
- Energy Loses in a Passenger Cars, Trucks and Buses
- Requirements for New Automotive lubricants
- Lubricant Regimes
- Test Instrument
- Example Results
- Conclusions

Company Profile

- Formed in 1987 by a group of research scientists from the Tribology Section at Imperial College, London
- Manufactures a range of tribology test equipment for the measurement of fundamental lubricant properties
- Based in West London, in the UK
- Turnover ~10 million Euros, 90% exported to over 50 countries Worldwide

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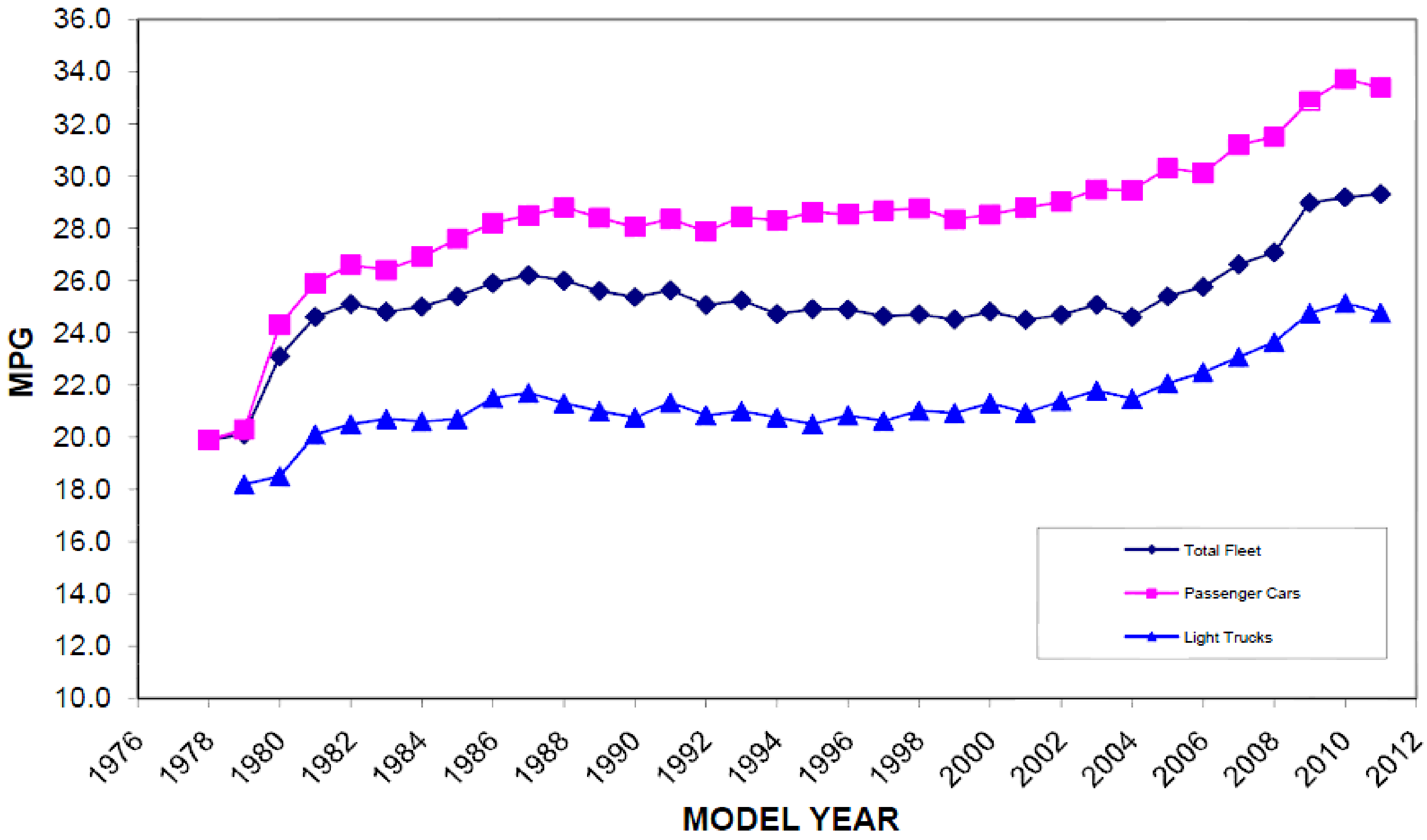
Fuel Economy – 1970's and 1980's

- 1975 – CAFE (Corporate Average Fuel Economy) set up in the US in wake of the Arab Oil Embargo
- Previously no target for fuel economy
- Called for doubling of fuel economy to 27.5 mpg within 10 years
- 1975-85 vehicle mileage doubled from 13.5 mpg to 27.5 mpg
- Mid 80's Ford and GM successfully lobbied the US government to bring the standard to 26 mpg, where it stayed until 1989

Fuel Economy – 1990's and 2000's

- 1990 – 2 senators sponsored legislation to raise fuel economy by 40% over a decade
- Passed by commerce committee but lost in the Senate – if passed, would be saving the US more than 1 million barrels of oil a day today
- 2009 Obama accelerated increase in CAFE standards
- Requires fleet-wide average of 35.5 mpg by 2016
- Increasing at an average of 5% annually, most passenger cars must achieve 39 mpg, and light trucks 30 mpg, by 2016

Fleet CAFE 1970's to 2012



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Passenger Car Growth

- Global passenger annual car sales rose by 7.2% to 66.6 million vehicles in 2012
- All regions grew except Western Europe
- Double-digit growth rates in North America and in the Asia-Pacific region
- Demand in South America reached an all-time high
- Global passenger car production rose by 6.0% to 70.5 million units in the reporting period

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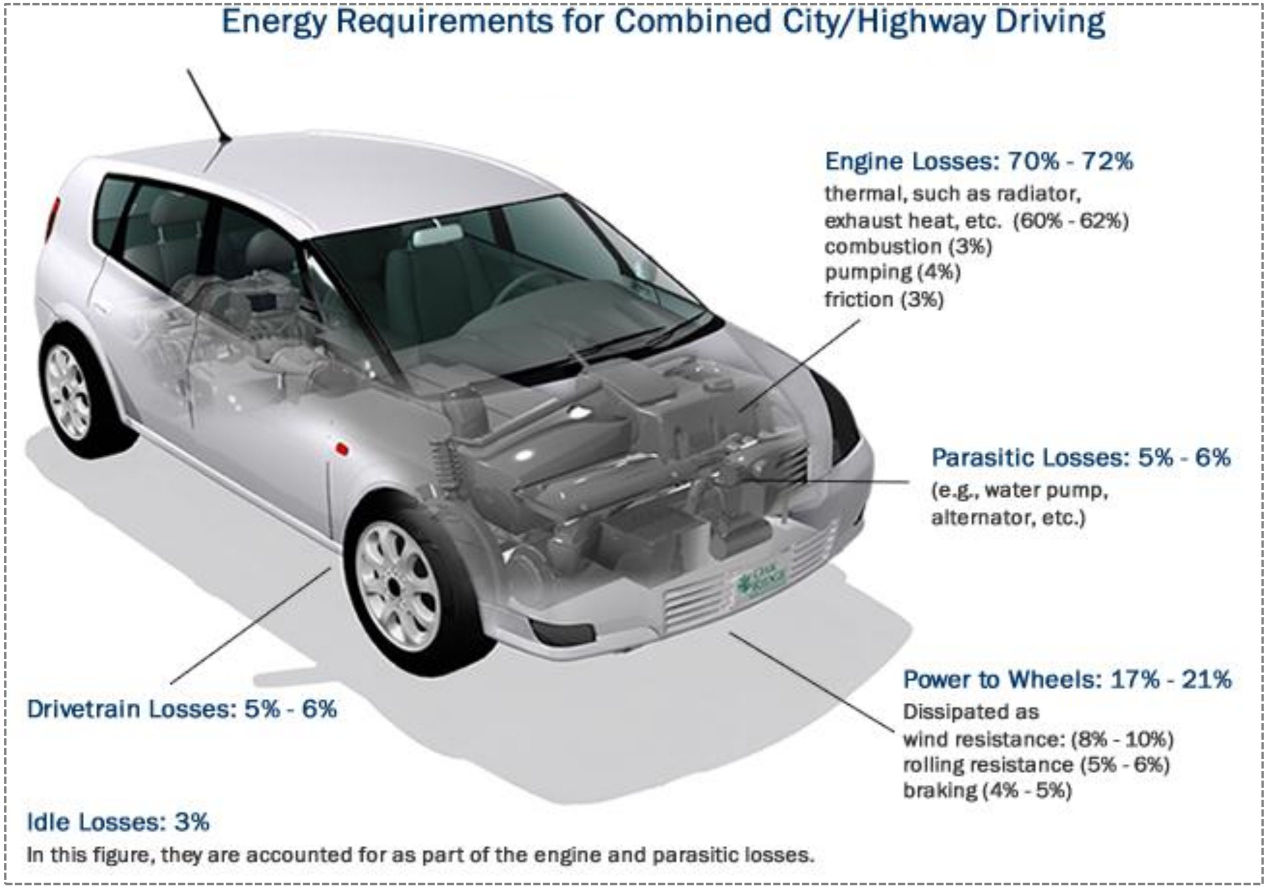
Energy Loses in a passenger car

- Only 17%–21% of the energy from the fuel you put in your tank gets used to move your car down the road
- Rest of the energy is lost to engine and driveline inefficiencies or used to power accessories
- Potential to improve fuel efficiency with advanced technologies is enormous



Energy Loses in a passenger car

- Energy output of fuel in a car engine breaks down to:
  - 29% is used for cooling
  - 33% is depleted in exhaust
  - 38% is used for mechanical energy (33% for friction losses and 5% in air resistance)
- Ways to reduce the loses include new surface coatings, surface texturing, lubricant additives, low viscosity lubricants, ionic liquids and low-friction tires

Energy Loses in Trucks and Buses

- In heavy-duty vehicles (HDV's), 33% of the fuel energy is used to overcome friction in the engine, transmission, tires, auxiliary equipment and brakes. Parasitic loses are 26% and only 34% is used to move the vehicle.
- 47.5 million gallons of fuel was used Worldwide in 2012 to overcome friction in HDV's. Any reduction in friction reduces exhaust and cooling loses as well.
- Globally a single truck uses on average 396 gallons of diesel fuel a year to overcome friction loses; a truck and trailer 3,302 gallons and a city bus 3,354 gallons.

Energy Loses in Trucks and Buses

- New Technology for friction reduction in HDV’s could lead to friction reduction of 14% in the short term (4-8 years) and 37 in the long-term (8-12 years)
- Hybridization of city buses and delivery trucks can cut fuel consumption 25-30%
- Downsizing internal combustion engine and using recuperative braking energy can also reduce friction loses
- The energy used to overcome friction in electric vehicles is estimated to be less than half of that in conventional diesel vehicles

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Current and Future Requirements for Lubricant Manufacturers

- Current engine requirements are met by SAE 5W-30
- Future engine oils will have to deliver
  - Better fuel economy
  - Long drain intervals (at least 20-30,000 km)
  - Excellent wear protection
  - Engine cleanliness
  - Compatibility with exhaust after-treatment devices
  - Environmental concerns – reducing CO_2

What's New in Engine Oils

- Group I could account for as little as a 1/3 of global capacity by 2017 (depends on bright stocks, waxes and other specialist products)
- Trend moving towards Group II and III base stocks globally – hydrotreating processes
- Group III processed by hydroisomerization offer similar performance advantage of synthetics, but can be manufactured in very large volumes

Group II and III Hydro-processing

- Hydrotreated base stocks advantages (over solvent refined counterparts) are
  - Generally higher VI
  - Less carbon residue
  - Lower Acid Number - Good for natural gas vehicles
  - Better oxidation resistance
  - Higher temperature stability
  - Greater purity 99.5% pure vs 80% solvent based
  - Better appearance

New vehicle types

- All electric cars have no engine oil as the bearings are sealed for life, however
- Hybrid cars have a lot of stress on the engine (due to frequently turning the engine on and off), so require special lubricants
- Natural gas cars use the same oil as conventional cars, but the oil degrades differently. As no fuel, the oil gets thicker over time and oxidation is higher (as they run hotter)

Future Engine Oil Requirements

- SAE 5W-20 or SAE 0W-20 viscosity grade oils, formulated with minimal SAPS in the additive package
- Lubrizol recently presented work showing how a typical ACEA C3 5W-30 oil will on average improves fuel economy by 2 percent compared to a conventional oil, while a typical ACEA C2 5W-30 yields a 2.7 percent improvement.
- Based on current work Lubrizol has performed with 0W-20 oils, they claim there is potential to improve the average fuel economy rating of around 4 percent

Future Engine Oils

- Fill for life?
  - Unlikely, currently 15,000 miles or 1 year (whichever comes first) is longest drain period
  - Unlike transmission, engine doesn't work in an enclosed system, so has to deal with outside elements (water, dust, pollen, dirt etc..)
  - Engine oils do a lot more than just lubricate. It also helps to control the engine temperature and clean the engine. In fact, cleaning engine components every time the engine fires is an extremely important function of engine oil.
  - Synthetics work better with prolonged higher temps, but the chemistry still breaks down eventually

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Fluid Film Regimes

Full Fluid Film

- Full separation of contacting surfaces
- No metal to metal contact –> no wear
- Bulk viscosity of the lubricant controls the film thickness
- Friction becomes a fundamental property of the lubricant

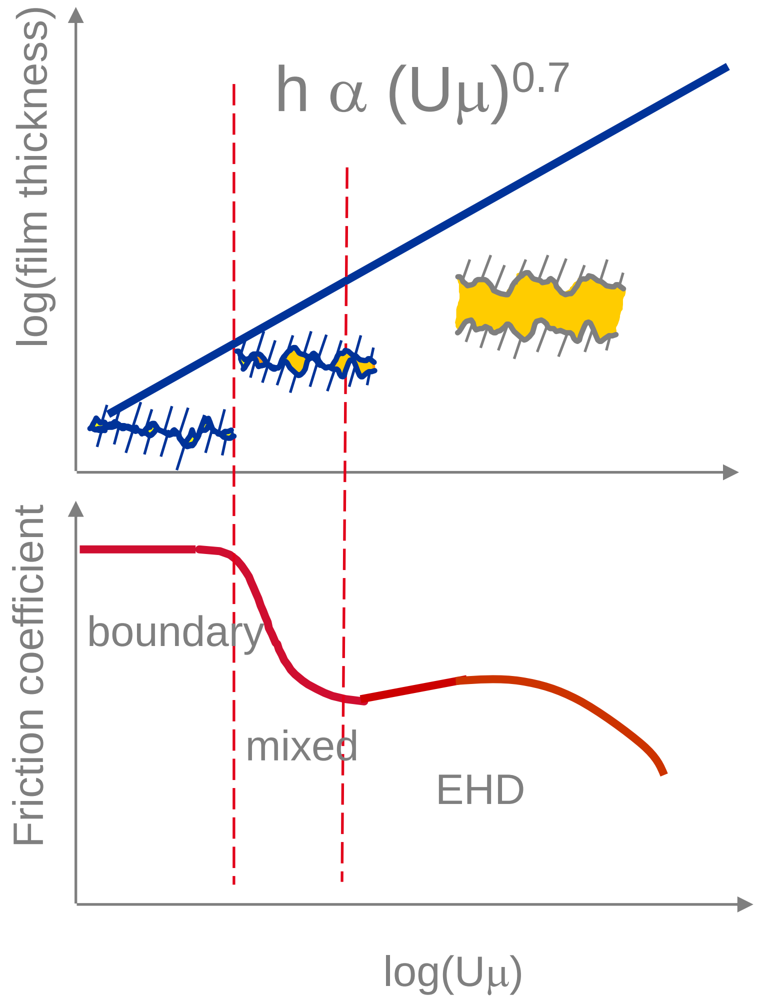
Mixed Regime

- Important since many practical machine components operate within it
- Performance-limiting phenomena such as wear and seizure occur
- Thin film (film thickness is lower than the composite surface roughness), resulting in occasional asperity interaction

Boundary Regime

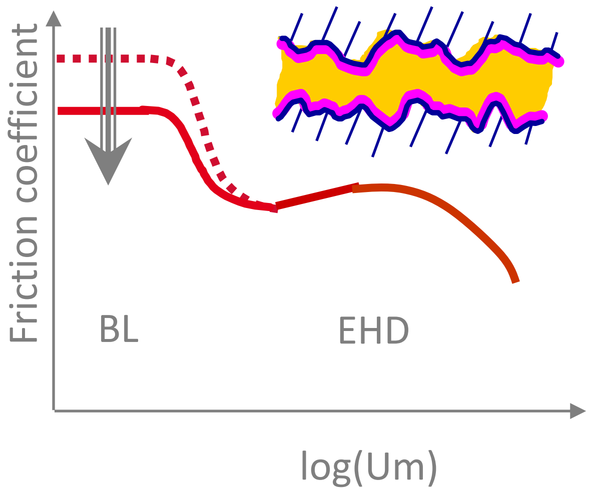
- Any fluid within the contact is unpressurized so that effectively all of the contact load is borne at asperity conjunctions
- Very thin film (film thickness much less than the composite surface roughness)
- Surface active additives control the friction

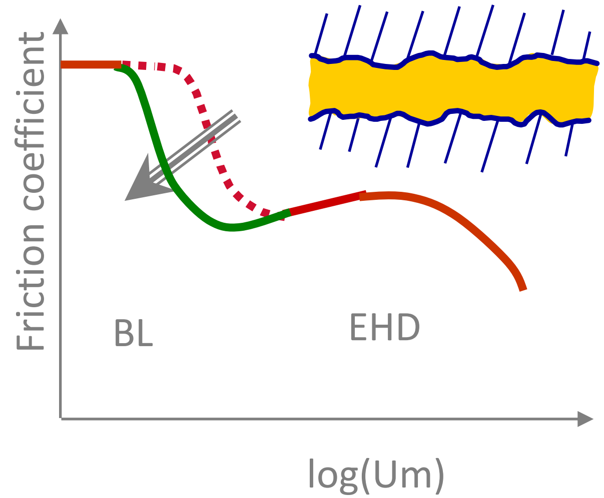
Fluid Film Regimes



How Might Additives Reduce Friction?

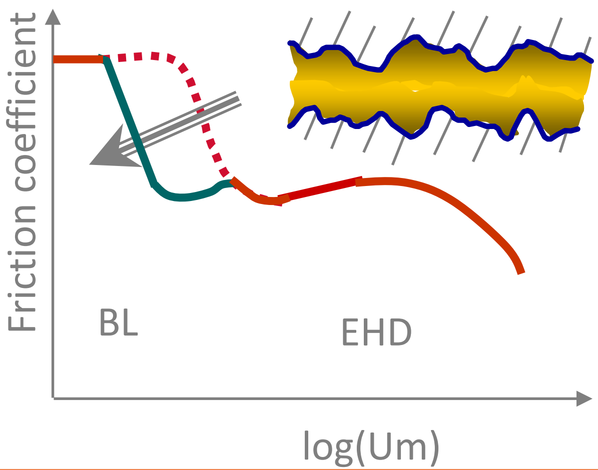
Form thin, solid-like film with low shear strength

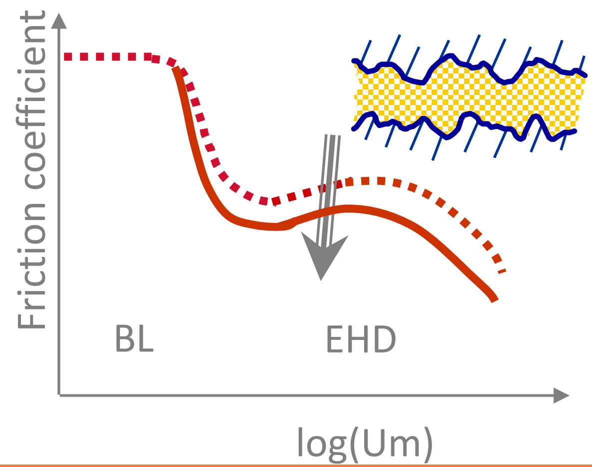




Smooth the solid surfaces

Form a viscous film on surfaces





Reduce EHD traction coefficient of the base fluid

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Mini-Traction Machine (MTM2) system:
Used for measuring traction (friction) properties of lubricants - *Over 150 systems Worldwide*

Applications of the MTM system

- Typical applications include :
  - Data gathering for fuel economy of automotive engine oils
  - Boundary additive performance evaluation
  - Investigation of traction measurements under EHL, mixed and boundary lubrication
  - Continuous Variable Transmissions (CVT) Investigations
  - Crankshaft Simulation
  - ZDDP Investigation

Test Conditions

Oils Tested

- Mineral Oil
- SAE90 Gear Oil (~SAE50 Engine Oil)
- 15W 40
- 0W 40
- 5W 30
- 0W 30

Specimens

52100 ¾” Ball (830-880 HV, 5nm Ra) against a 45mm smooth disc (750-800 HV, 5nm Ra)

Conditions

- Load 30N (0.94 GPa)
- Speeds 0.01m/s – 1m/s
- SRR 50%
- Temperatures
  - 40 degrees C
  - 60 degrees C
  - 80 degrees C
  - 100 degrees C

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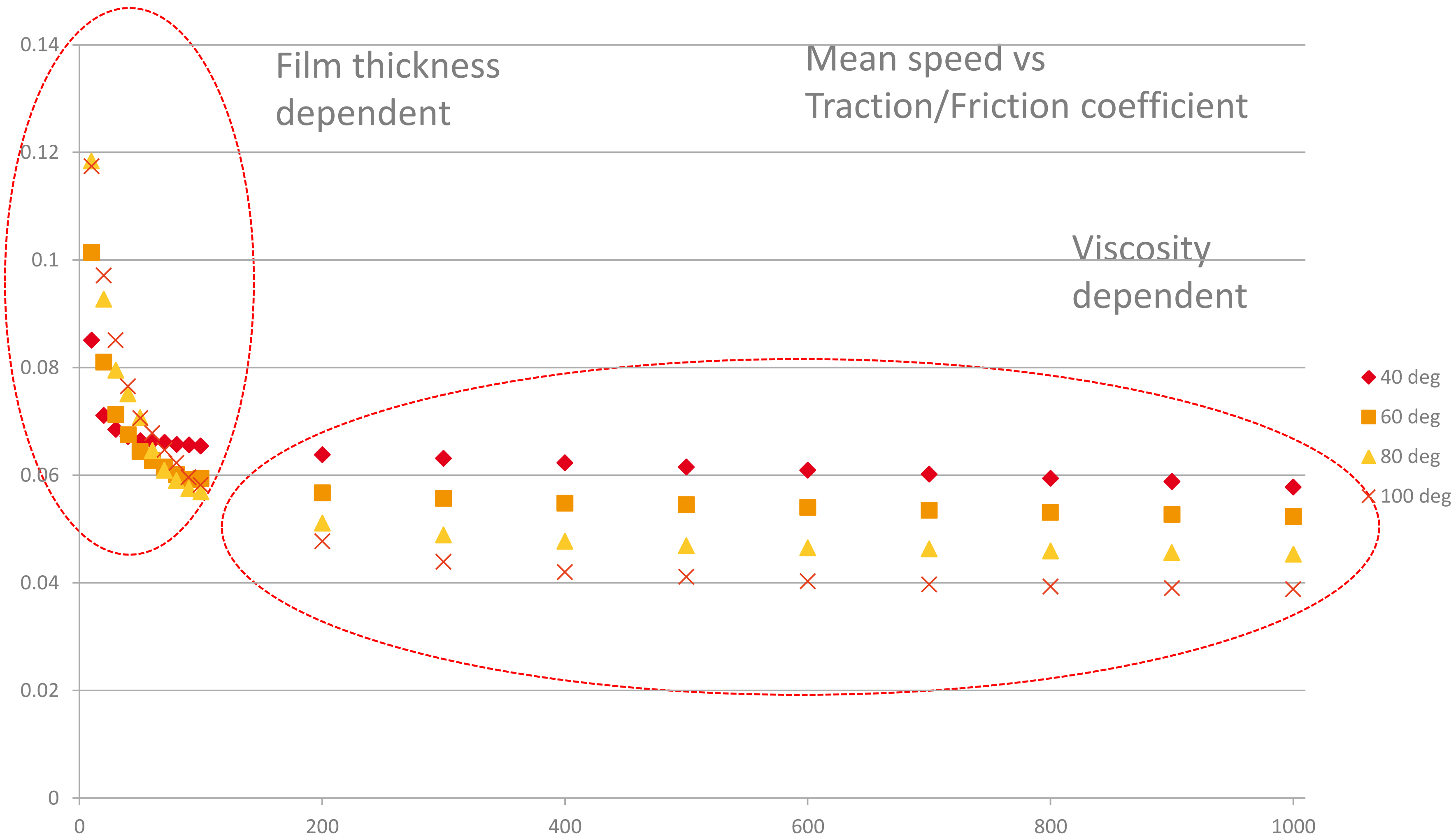
Results for Mineral Oil



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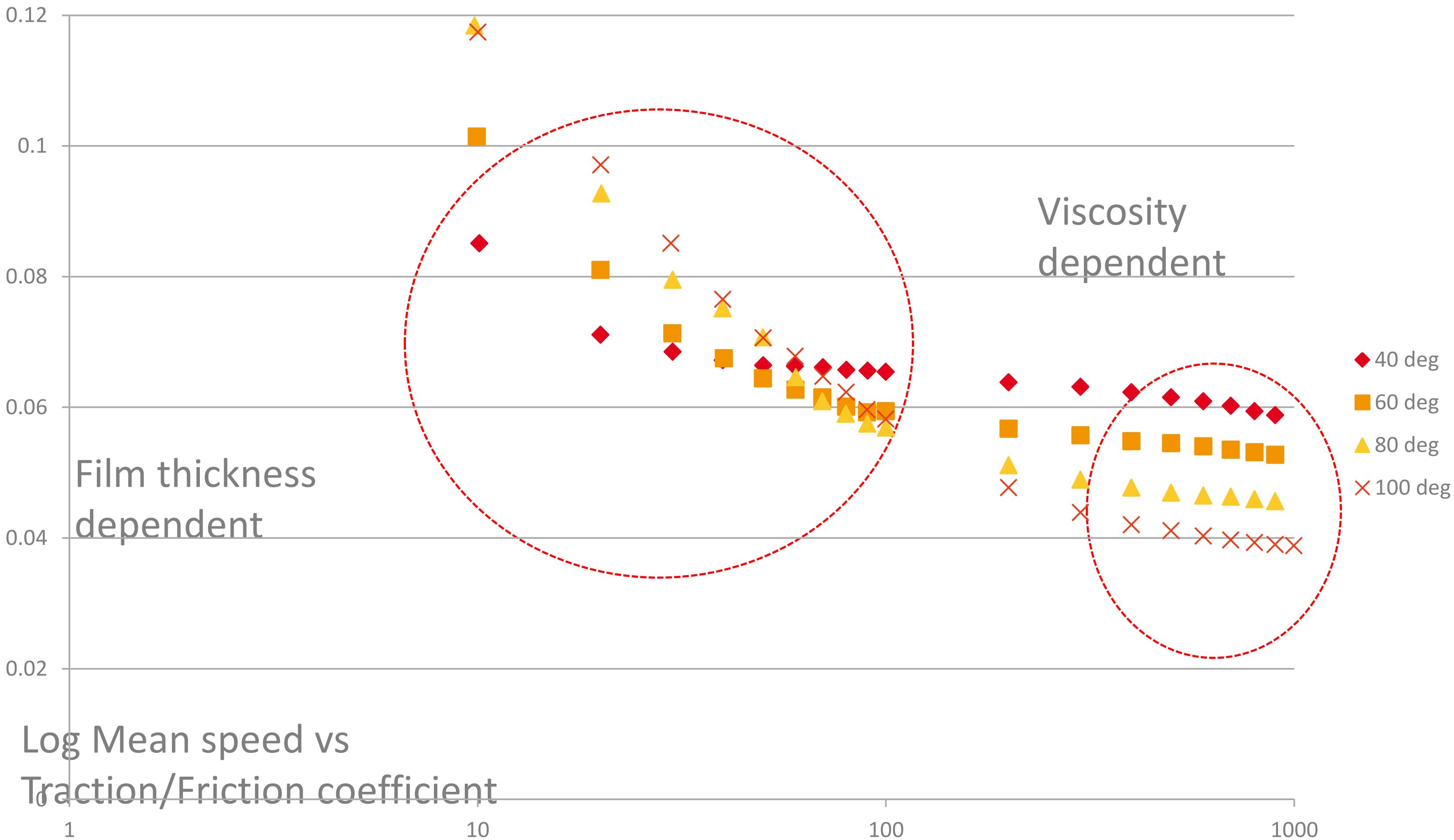
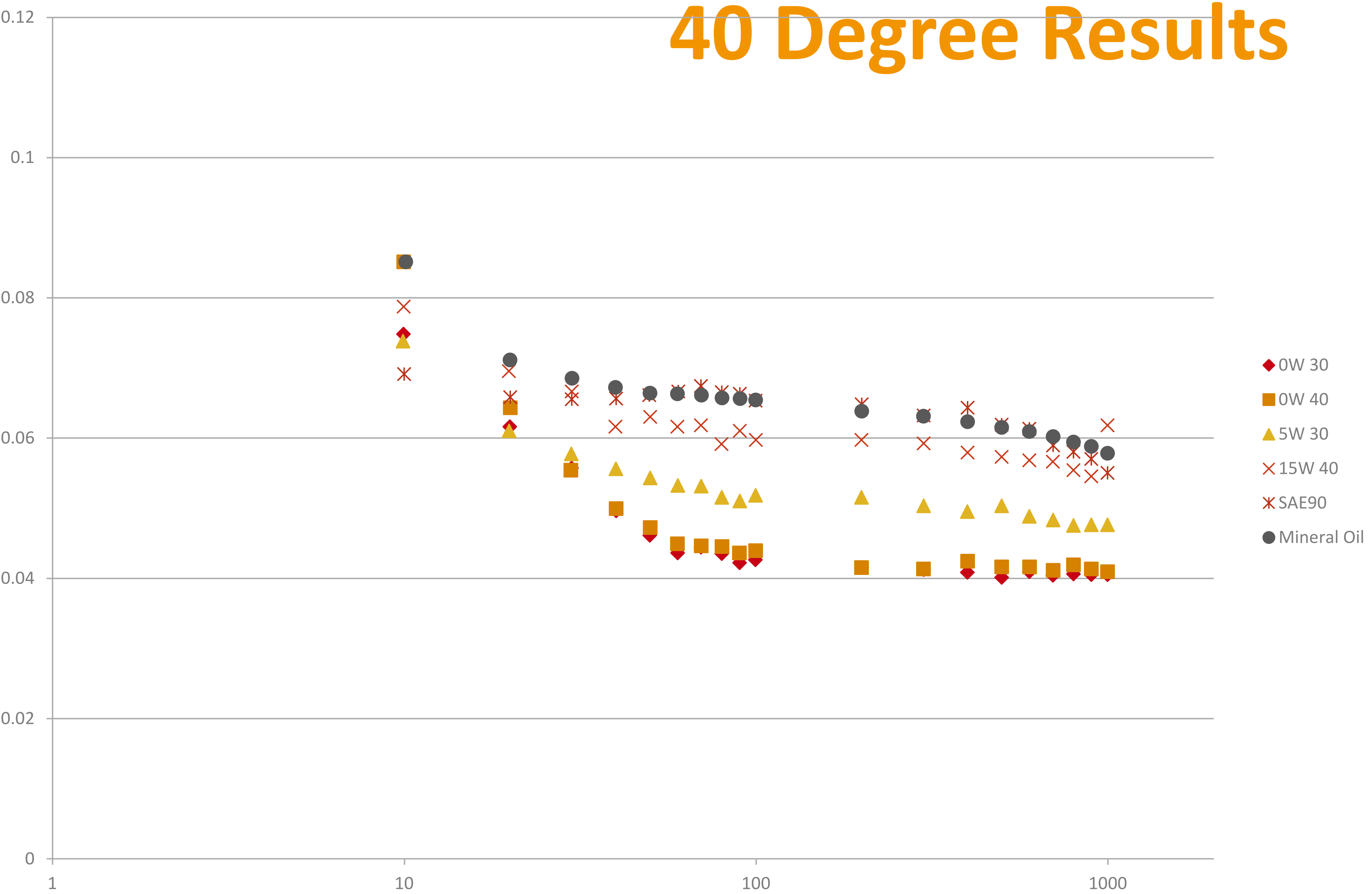
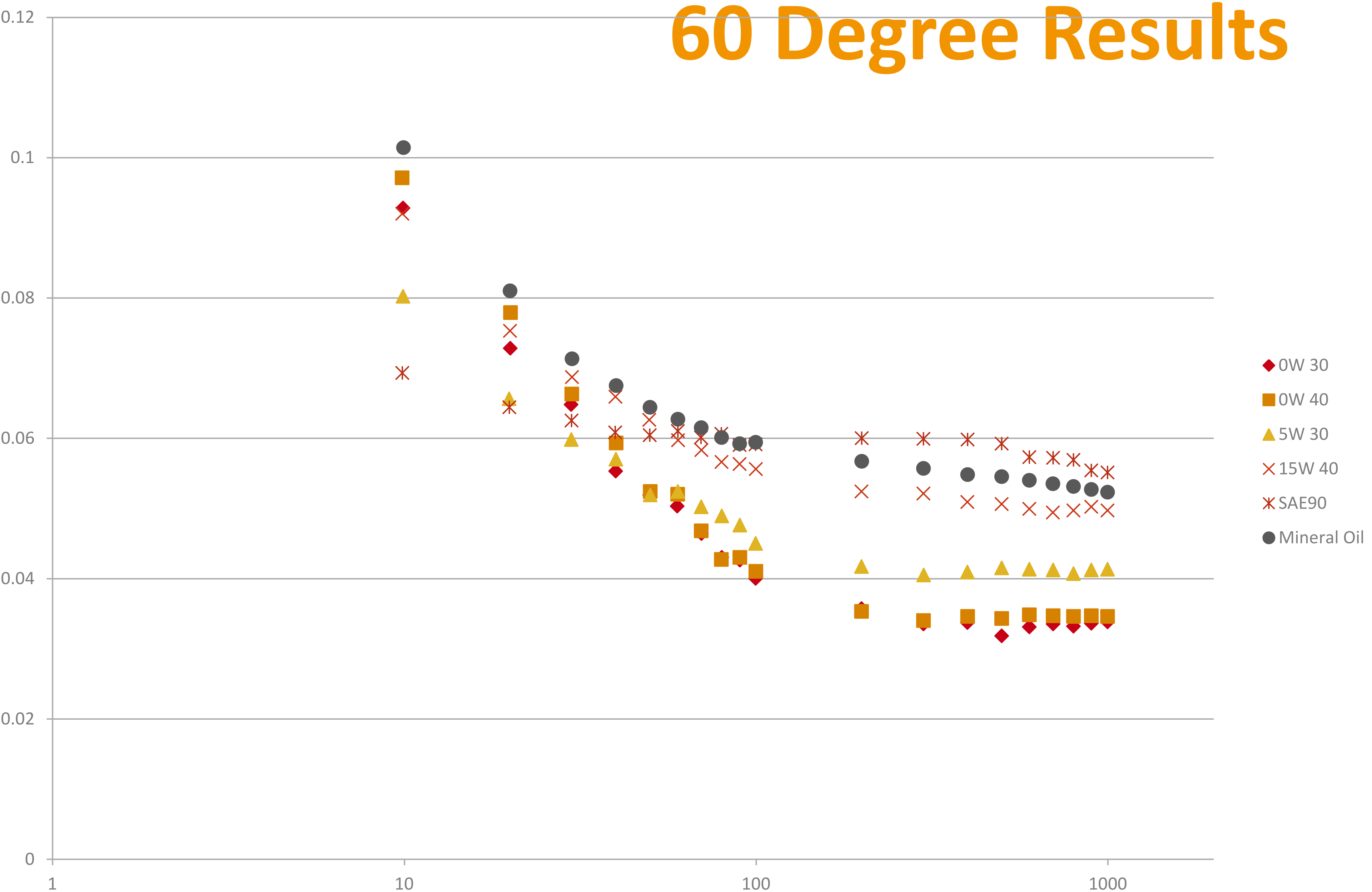


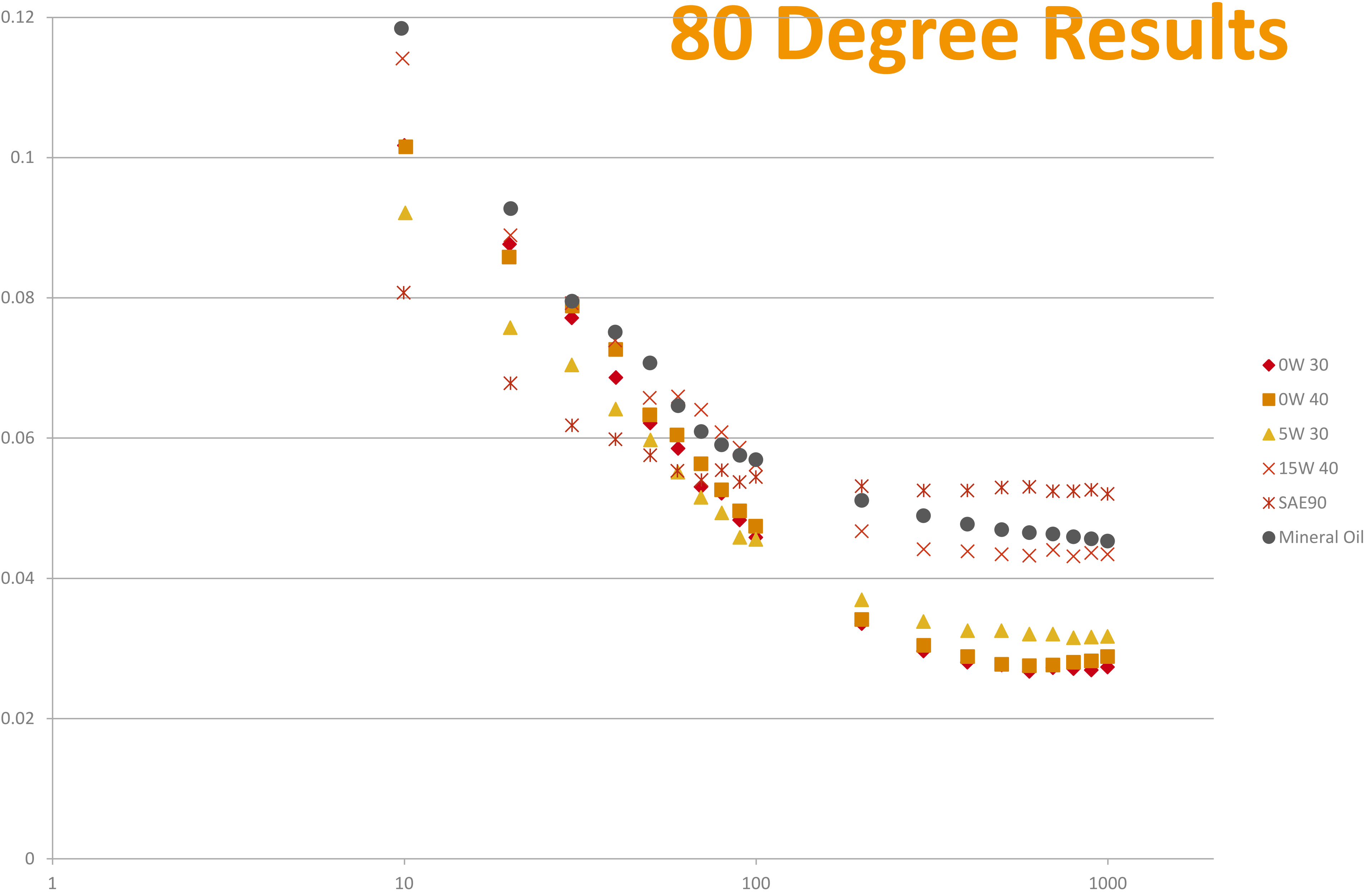
40 Degree Results



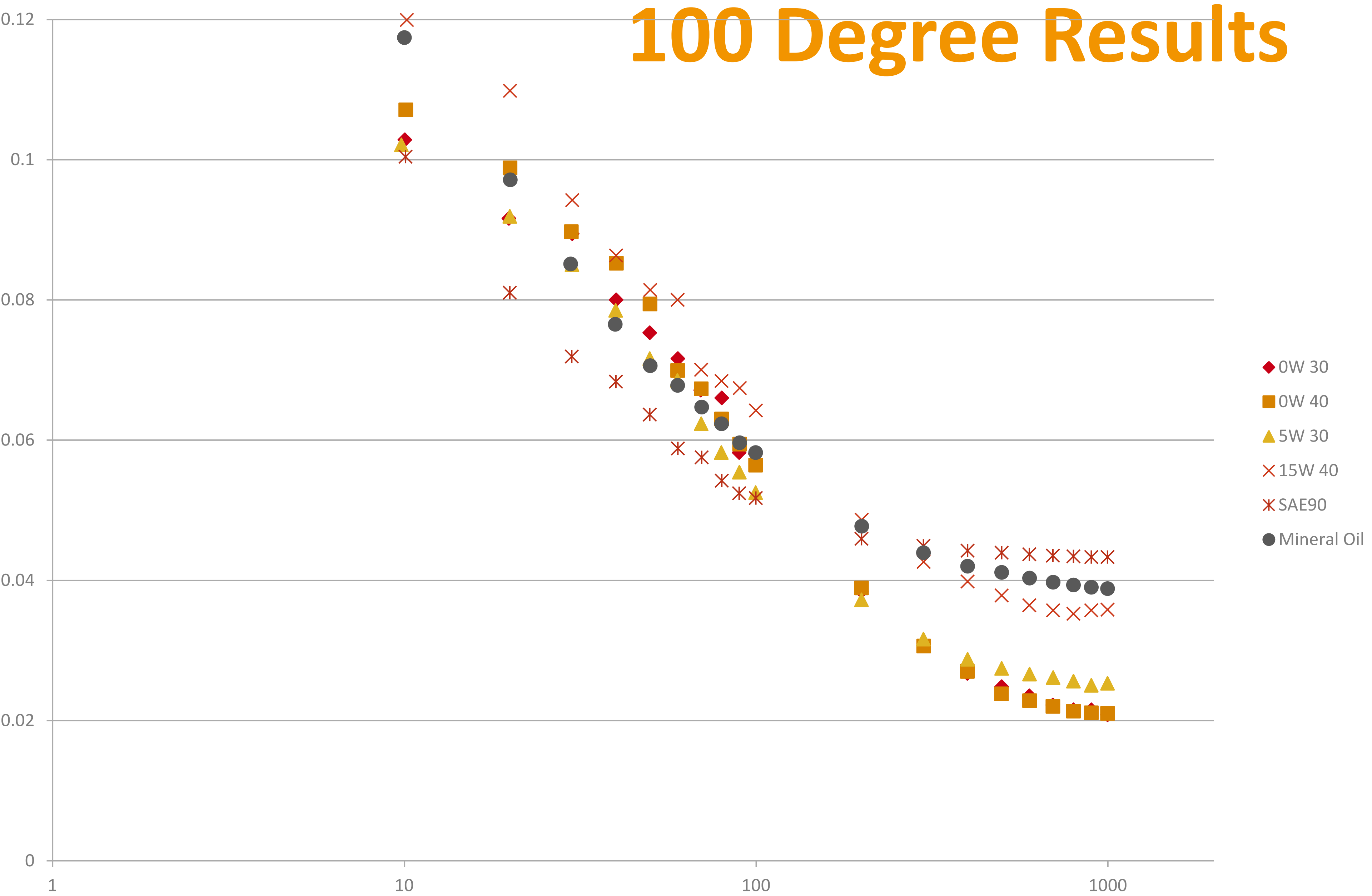
60 Degree Results

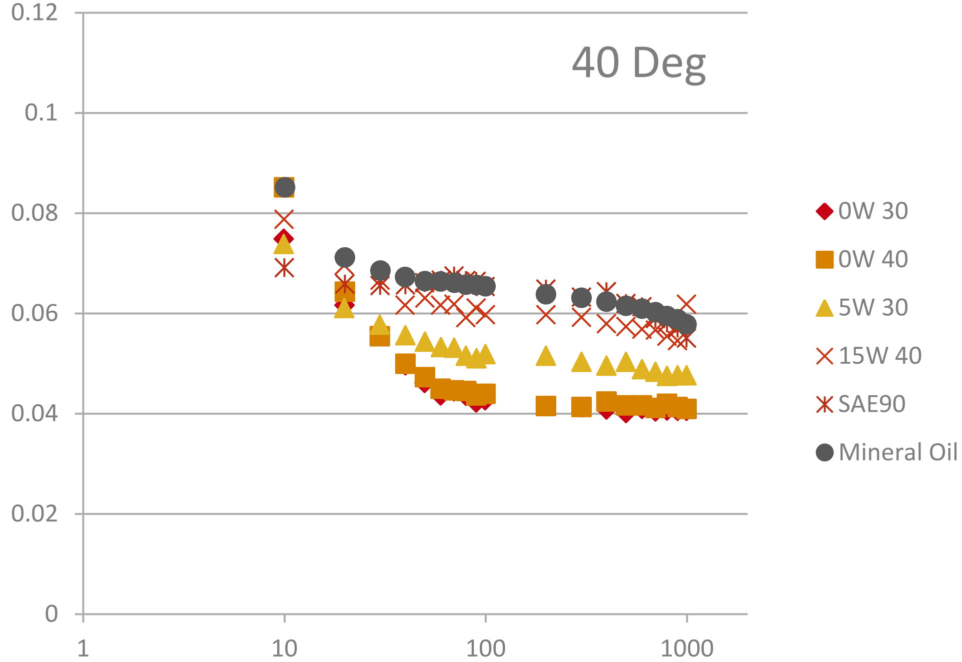


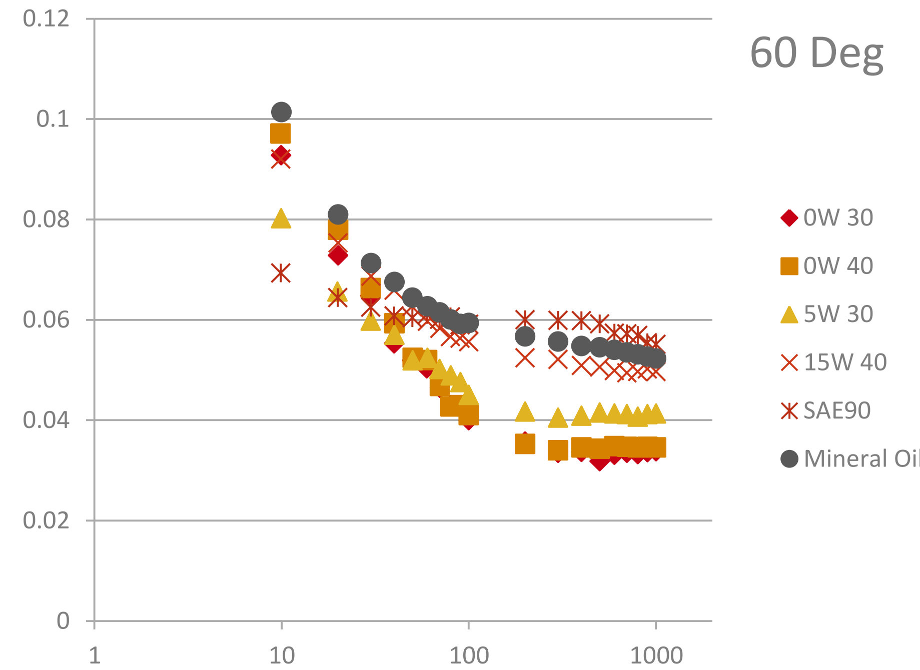
80 Degree Results

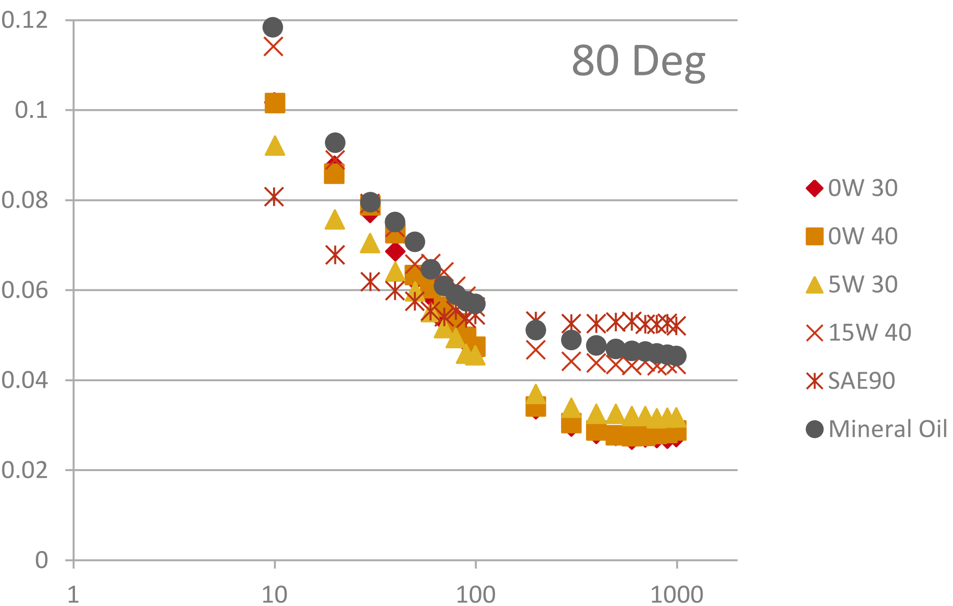


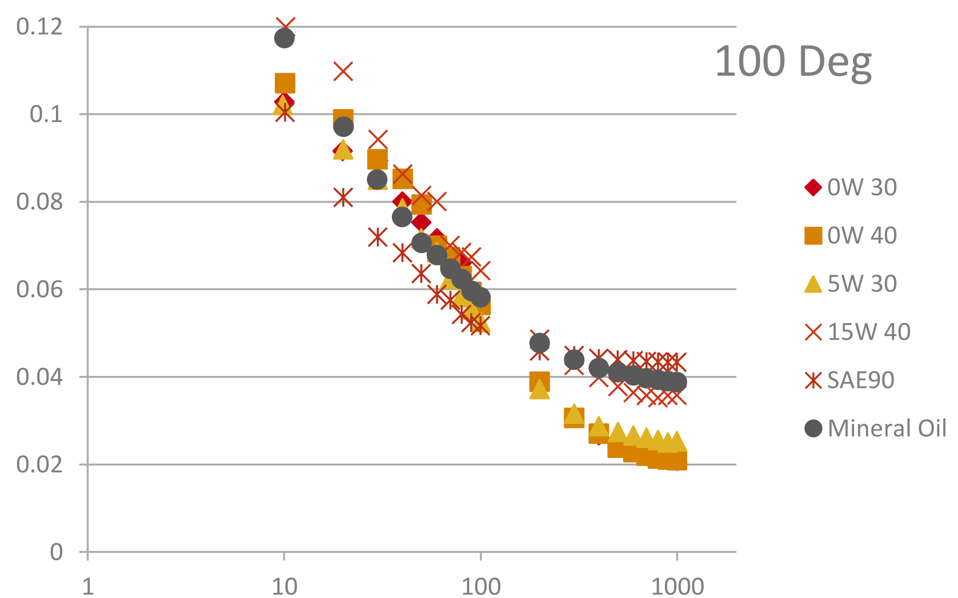
100 Degree Results











Dr Rich Baker – OilDoc Conference 2015

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Lubricant Efficiency Today

- The best passenger car engine lubricants are currently about 4-5% more efficient than their early 1990s counterparts as a result of lubricant development.
- This increase in efficiency corresponds to an annual reduction of nearly 4×10^{10} kg (about 0.1%) of global man-made CO_2 emissions*.

* Based on 600M cars, 10k km/yr, 150 g/km CO_2, 4% reduction, 2010 total 30.6 Gtonnes.

Bench top Test Equipment

- Most of this work developed using commercially available desktop tribology equipment from by PCS Instruments.
- From 2008-2012, The MTM and PCS High Frequency Reciprocating Rig (HFRR) were cited in 380 US patent applications and in 113 granted US patents.
- PCS test rigs have been sold to over 40 University research groups world-wide, making them one of the most widely-used categories of equipment in tribology research laboratories.

Future - Affecting Additives

Trends for Autos, Engine Oils

- Additives R&D investment rising
- Efforts to reduce R&D Costs
- Rising Oil Demand in Asia and Middle East
- Pressure to Reduce Fuel Economy
- Rising Performance Demands
- Pressure to use less metals in engine oil
- Increase in Exhaust gas recirculation
- Increase in Exhaust after-treatment
- Growing use of bio-fuel

Effect on Additive Companies

- More than 5% of sales goes to R&D – main barrier for entry
- Focus on molecular engineering, simulation and low cost tests
- Additive manufacturing will follow in order to reduce costs
- Reduce viscosity; ↑ use of friction modifiers
- Need for customized additives in harsh environments
- New generation of detergents, antiwear agents
- Need for better oxidation control, more dispersancy, better soot-handling capability
- Need for additive technologies low SAPS
- Need better control of viscosity, oxidation and sludge, better corrosion inhibition

Conclusions

- Fuel economy has improved significantly over the past 40 years, driven by
  - Legislation (initial main driver, but ongoing pressures)
  - Engine Design – better components
  - Consumer – both cost and environmental issues
- Bench top tribology test equipment is helping (in part) to improve further fuel economy for the next generation engine oils

Thank you

rich.baker@pcs-instruments.com