Friction and Wear Reduction using Polyalkylmethacrylate Viscosity Index Improvers

Hitoshi Hamaguchi
Degussa Japan Co., Ltd.

Michael Müller, Torsten Stöhr
RohMax Additives GmbH,
Darmstadt/Germany

Jingyun Fan, Hugh A. Spikes
Tribology Section, Imperial College,
London/UK
Polyalkylmethacrylates - a class of highly versatile VM polymers

$R_f = \text{wide range of N, O, S, P-containing functional groups are available}$

$R = \text{C1-24 alkyl, linear or branched}$
Scope of our research

- Establish structure-property relationships of polymeric VIIIs with regard to their tribological performance
- Investigate film forming mechanism
- Identify most effective VII technology to provide improved film forming properties and reduced friction
- Prove beneficiary effects of such VII technology in different lubricant applications
  - Wear reduction
  - Fuel / energy efficiency improvements
- Explore interactions of PAMA VIIIs with different package components, identify synergistic and antagonistic effects
- Transfer performance improvements to fully formulated fluids and application-related bench and performance tests
Ultrathin film interferometry to measure boundary film formation

Measures the lubricant film thickness formed between a rolling steel ball and a silica-coated glass disc, as a function of rolling speed, down to < 2 nm.
Minitraction Machine (MTM) to measure friction

Measures the friction coefficient of the lubricant film between a sliding-rolling steel ball and a steel disc as a function of rolling speed.
High Frequency Reciprocating Rig (HFRR) to measure wear

Measures friction and wear properties of the lubricant film between an oscillating steel ball and a flat steel specimen under pure sliding conditions.
Polymers with functional groups clustered in a block gave clear **thick** and considerably viscous boundary films.

Polymer is adsorbed at the metal surface – boundary film contains higher polymer concentration than bulk fluid.

Boundary film is stable and survives high pressure rolling-sliding contacts.
In correlation with film thickness results, non-statistically distributed block copolymers gave a very large reduction in friction at low speed.
There is a clear dependence of friction from molecular weight of the block copolymer with high molecular weights, resulting in thicker boundary films and lower friction at low speed.
Friction depends only slightly on the disp. polymer concentration. Even small concentrations are sufficient to form a stable boundary film through adsorption at the metal surface.

Up to about 90% of the dispersant copolymer was substituted by an amount of non-dispersant PAMA sufficient to adjust to the same KV120.
“Chelating” functional groups with a multitude of hetero atoms promote adsorption and give rise to low friction at low speed.
Even in the presence of a fully formulated 75W90 gear oil, the DMAEMA block copolymer shows boundary film formation and leads to significantly lower friction at low speed.

**Formulation based on group 3 oil.**
Package contains:
- Dispersant
- S-based EP additive
- Antioxidant
Friction and Wear: HFRR Results 1

- Distinct friction reduction by dispersant block copolymer even under pure sliding conditions
- Even small polymer concentrations are sufficient to significantly reduce friction
Friction and Wear: HFRR Results 2

- Significant friction reduction with increasing copolymer concentration after prolonged “rubbing” time
- Tribochemical reactions in viscous boundary film?
Friction and Wear: HFRR Wear Results

- Average wear scar diameter shows excellent correlation with friction coefficients determined by HFRR
- Boundary film forming dispersant PAMA copolymers protect steel surface and reduce wear significantly
Conclusions

- PAMA VM polymers have been shown to form thick viscous boundary films
- Polymer needs to contain specific functional groups to adsorb strongly on polar metal surfaces
- Functional groups should be clustered within the polymer
- With increasing polymer molecular weight, film thickness at low entrainment speed increases and friction decreases
- Even small polymer concentrations are sufficient to form stable boundary films through adsorption at the metal surface
- Introduction of spacer groups or chelating functional groups can significantly improve the polymers’ ability to form boundary films
- Thick PAMA-based boundary films are stable even under pure sliding conditions and over extended periods of strain
- PAMA copolymers protect the metal surface and significantly reduce wear
Acknowledgement

Jingyun Fan, Ksenija Topolovec-Miklozic, Prof. Hugh A. Spikes
Imperial College, London

Klaus Schimossek, Marty Bollinger and Boris Eisenberg
RohMax Synthesis Labs, Darmstadt and Horsham

Alex Dardin, Christoph Wincierz and coworkers
RohMax Tech Service Labs Darmstadt