Additive: ALUB®

(Is using by Ab Nanol Technologies Oy as Additive under their trade name)

New and revolutionary lubrication technology

Agenda

- Introduction ALUB®
- The ALUB® additive technology
- Comparative SRV test results
- Lab test results
- FE8 WEC Test

WHAT IS ALUB®?

- ALUB® is a unique micelle technology-based lubricant additive

- ALUB® forms a nano-thin protective layer on, and only on, the friction surfaces, thanks to perfectly suspended soft metal ions contained in the lubricant.

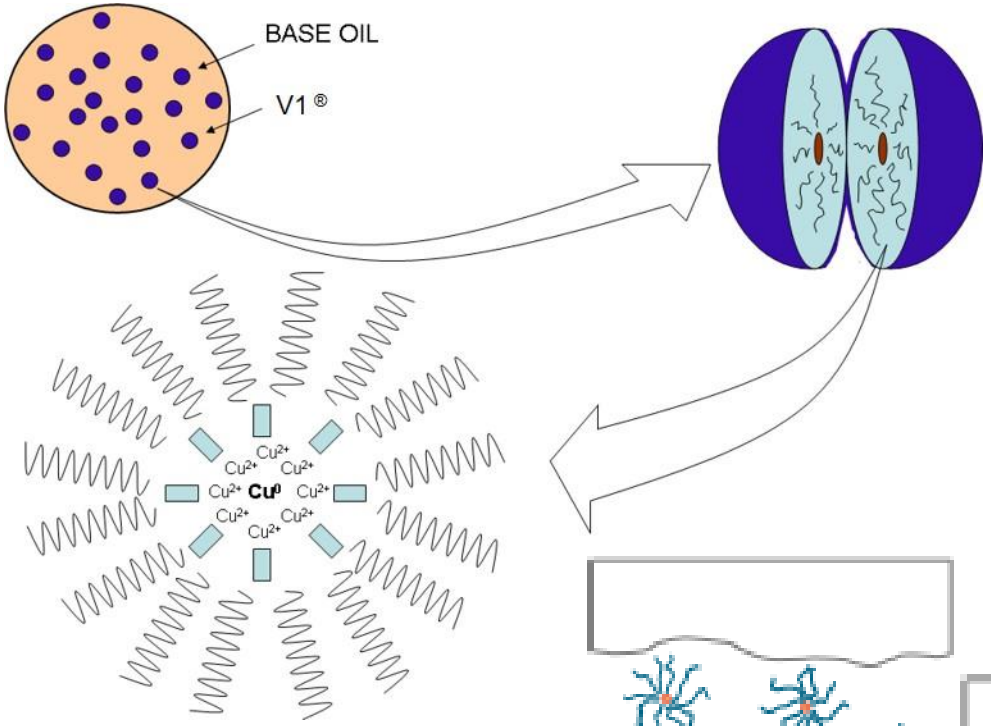
  → *Reducing friction and operating temperature of the components*

  → *Lowering wear and protecting the friction surfaces*

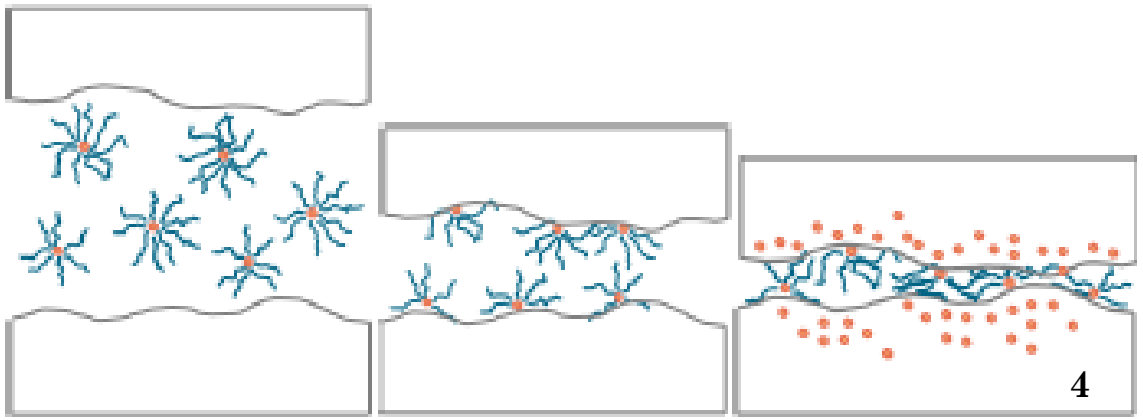
  → *Extending lifetime of components and lubricant*

  → *Increasing the efficiency of industrial applications*

ALUB® TECHNOLOGY

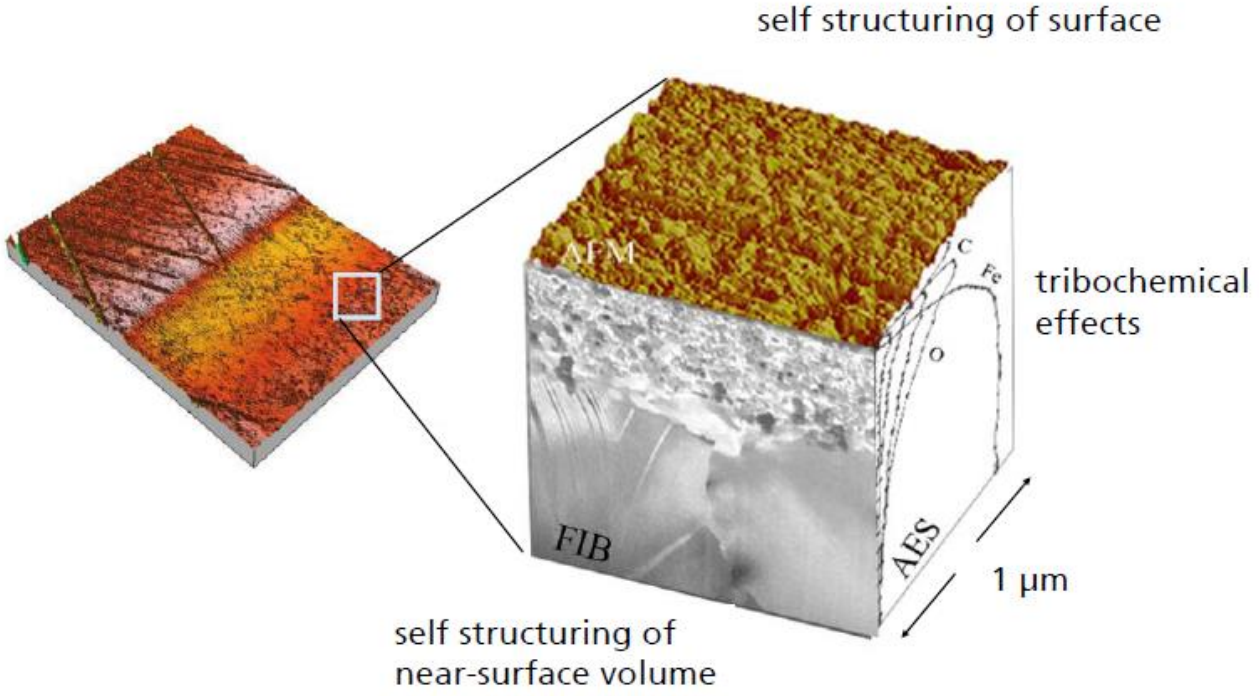


The ALUB® additive is kept dispersed in the lubricant oil thanks to a unique reversed micelle (RM) structure.



ALUB® TECHNOLOGY

- Third Body Formation



Source:

ALUB® TECHNOLOGY

Surface Activation

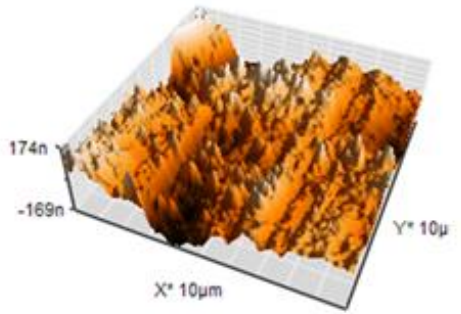
- Interaction between surface asperities → wear process
- Release of radicals/electrons (e^-)

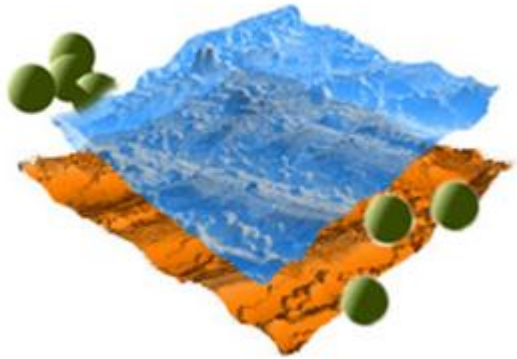
Redox Reaction

- Reduction of copper ions (Cu^{2+})
- $Cu^{2+} + 2e^- \rightarrow Cu^0$

Formation of Copper Layer

- Protective copper (Cu) layer formed only on the friction surfaces



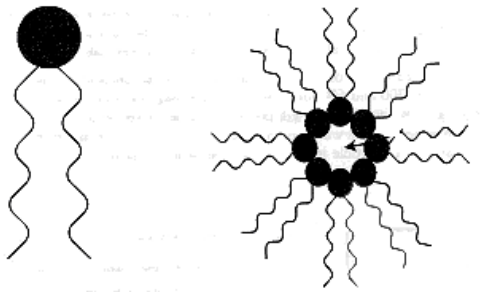


Source: Fraunhofer KIT MIKROTRIBOLOGIE CENTRUM µTC

ALUB - Composition

- There are indications that the ALUB additive is arranged as hard core reverse micelles (RM) in hydrocarbon environment.
- The micelles are arranged to larger agglomerates. agglomerates up to 1 micron (1μm) have been analyzed.
- Micelle size ~30-40nm.

- Hydrocarbon tails from the copper(II)oleate are exposed to the solvent, while the polar heads point toward the interior, possibly towards a Cu^{2+} / CuO / Sn/Cu core.



NANOL/ ALUB - TECHNOLOGY

- Antiwear and antifriction based on the formation of a tribo-chemical film coating.
- Formation of metallic copper durable film on the friction surfaces due to following tribochemical reaction (*selective transfer*):
- $Cu^{2+} + 2\ e^- \rightarrow Cu^0$
- $CuO + e^- \rightarrow Cu^0$
- $2\ Fe^{2+}$ (or Fe^0) + $3\ CuO + 2H_2O \rightarrow Fe_2O_3 + 3Cu^0 + 4H^+$

Competitive Advantage

- Theory well documented with >30 years of solid academic research
- Unique technology; self structuring nano-thin protective layer (no S or P!)
- Excellent test results
- Extensive application potential

Experiences

- Laboratories
- Shipping
- Railways
- Mining
- Trucking
- Industrial applications
  - Bearings
  - Gear boxes
  - Compressors

How to benefit from ALUB®

- Instead of adding the combination of all chemical additives, ALUB® is the only additive you need to add into greases!

- Use our suggested volume of ALUB® in your greases, you will have the better performance meanwhile the cheaper production cost!

INSTITUTE REPORTS

Fraunhofer-Institut für Werkstoffmechanik, Mikrotribologie Centrum µTC (Germany): F[illegible]

Fraunhofer KIT
MIKROTRIBOLOGIE CENTRUM µTC

Status report of friction and wear tests of marine oils with and withou additives

By means of a PLS simulator friction and wear between a chromium-plated steel piston ring and a gray cast iron liner was evaluated in real-time to determine friction coefficients and wear rates. The test setup simulates the upper dead center of an engine. The machine parts were selected to be similar to original marine diesel engine part oils with different concentrations (0.3%, 1%, 3%) were compared with a pure marine diesel engine oil. Figure 1 shows the test setup with the PLS and the RNT wear measuring unit. All tests exhibited wear rates smaller than 5 nm/h which are common for diesel engines. However, it has to be pointed out that Nanol 0.3% showed a three-times lower wear rate than the pure marine oil, i.e., 1.1 nm/h in comparison to 2.8 nm/h!

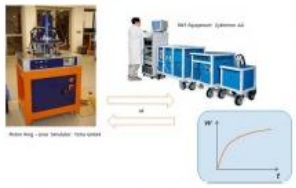


Fig. 1: Piston ring – liner simulator connected to a radionuclide wear measurement system.

With respect to friction the PLS showed only minor reductions of friction due tc additives. Since in the PLS the piston ring moves with a constant velocity of 0.2 m/s (except at the turning points) an additional test with a high-resolution ball on flat setup was used. With this machine the velocity range between 1E-4 m/s and 1 m/s was covered. To compare the output of this

It was shown that additives induce a significant reduction of friction.

dead center.

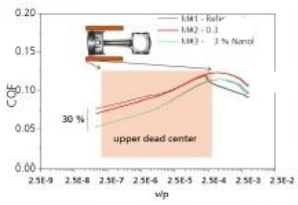


Fig. 2: Ball on flat measurements.

The brown inset of Fig. 2 indicates the w/p ratio acting in a real combustion engine. With the PLS only the range around w/p = 5E-4 was covered, explaining the small differences between Nanol and the reference oil. However, when the full v over p range is covered, a reduction of friction of up to 30% was detected.

The third group of experiments was carried out with a ball on flat setup as well. This time the ball was decelerated to receive a mixture of rolling (90%) and slipping (10%). The test was run with pressures acting in ball bearings. At a pressure

With respect to wear the additives do not impose a hazard to the engine, on the contrary, in the tested stressing range clearly reduced wear.

energetic corridor exists were the additive performs best. With respect to wear the additives do not impose a hazard to the engine, on the contrary, in the tested stressing range Nanol clearly reduced wear. The acting friction-reducing mechanism, however, is still under investigation.

VTT – Technical Research Centre of

VTT

15.10.2013 1 (1)

Nanol Technology
Helsinki

Dear Johan,

On your request I would like to summarise my view o based on the experience we have at VTT

The recent results from field testing by Technology show that they nave found a way to further develop and benefit this technology in an impressive way. The reports I have seen are convincing that the Nanol additive can reduce friction considerably in marine engines.

At VTT we have recently managed to reproduce this lubricating mechanism with marine oils including additives in our twin-disk test equipment. Our first tests showed that in elastohydrodynamic rolling-sliding conditions the friction was reduced by about 10% whe was added to the oil. These contact conditions represent a considerable part of the lubricating contacts in an engine. Our recent published studies show that in an internal combustion engine a reduction in friction would have a triple energy consumption effect on fuel savings because it will at the same time also reduce both exhaust and engine cooling at a similar rate.

This friction and wear reducing effect has up to date been shown in various conditions including boundary, mixed, elastohydrodynamic and hydrodynamic conditions. Still the fundamental mechanism of this lubricating mechanism is not fully understood and our joint investigation on this continues. For this is further investigations needed in controlled laboratory conditions with tribological test equipment like pin-on-disk, twin-disk and piston-ring simulators.

Sincerely

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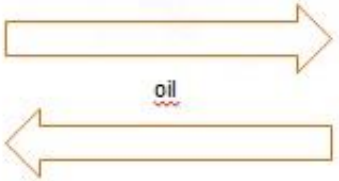
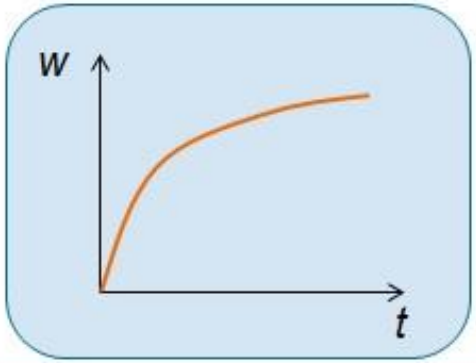
Our recent published studies show that in an internal combustion engine a reduction in friction would have a triple energy consumption effect on fuel savings because it will at the same time also reduce both exhaust and engine cooling at a similar rate.

RNT Test
Continuous Wear Measurement

Piston Ring – Liner Simulator: Tetra GmbH

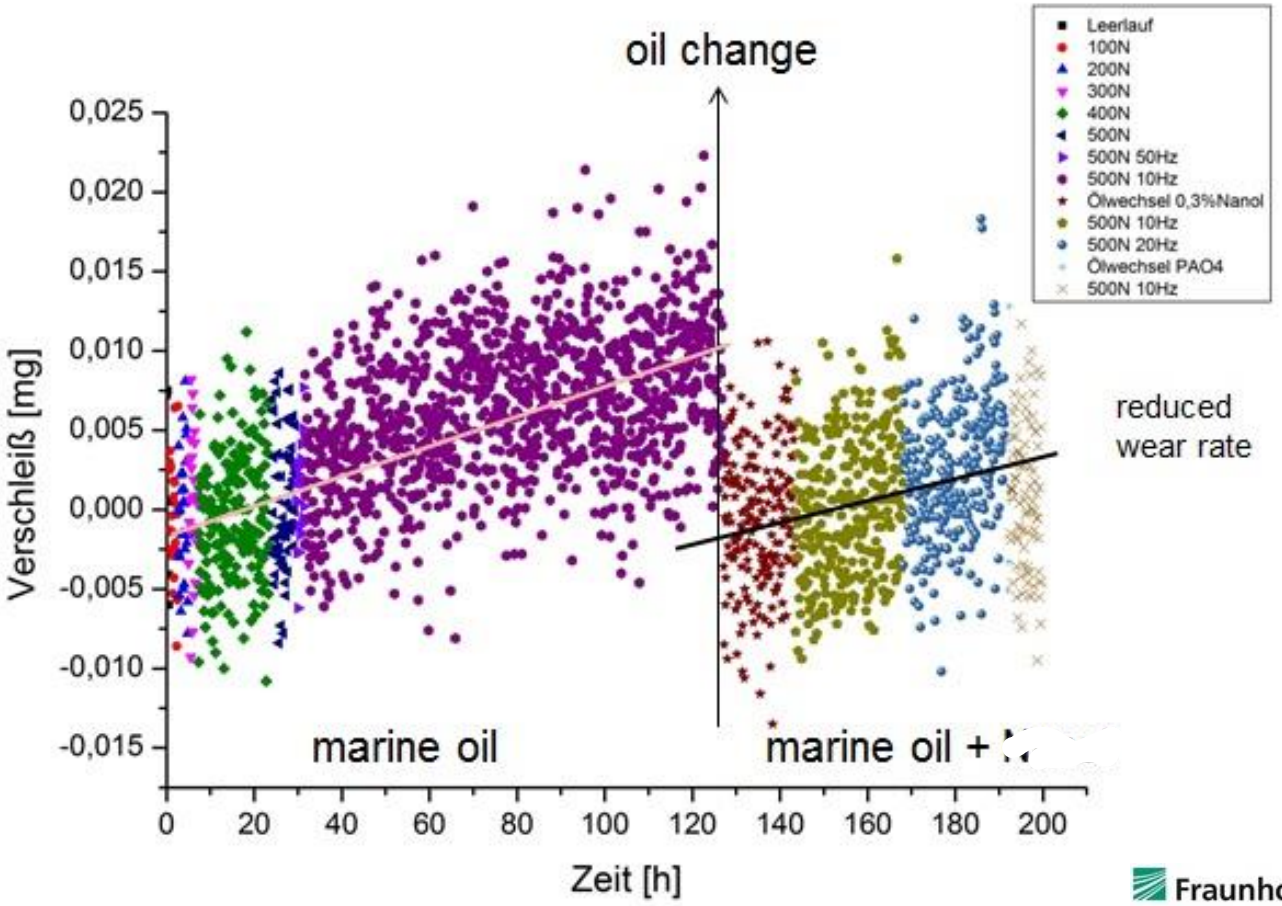
RNT Equipment: Zyklotron AG





RNT Wear Test

- RNT (Radionuclide Technique) wear test: marine oil and marine oil+Nanol[1]

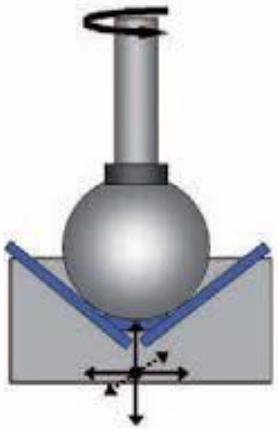


Fraunhofer IKT
MIKROTRIBOLOGIE CENTRUM µTC

Anton Paar Viskosimeter

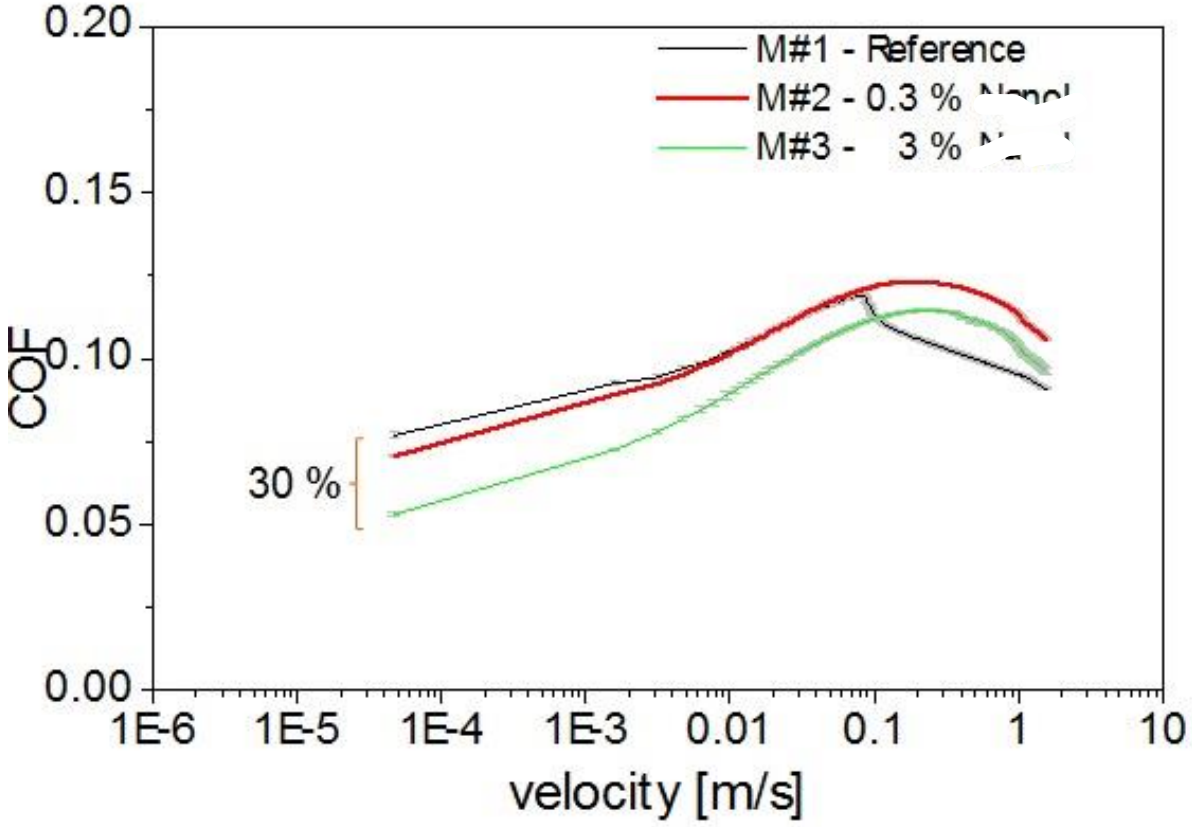
Tribometer Tests Ball on Flat

- F_N = 25 N, v = 0 – 1,5 m/s
- p = 433 MPa
- ball diameter 1,27 cm



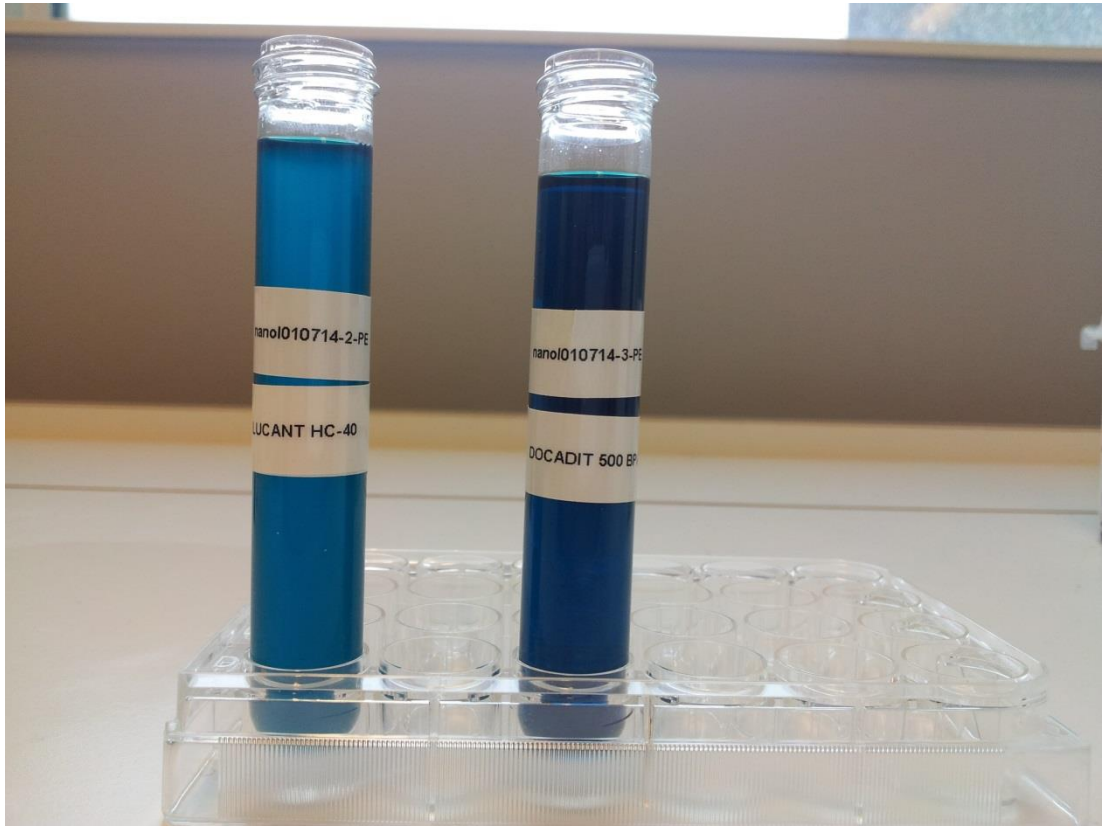
ANTON PAAR VISKOSIMETER

- Friction test marine oil and marine oil + N[illegible]l:
  30% lower friction with ALUB



Solubility in PAO and Ester oils

- Solubility of 1%, 2%, 3% and up to 10% of ALUB® tested
- In all samples ALUB perfectly soluble



Thank you for your attention!