Whitepaper

EAL: The next generation

Lubricant innovations for the shipping industry

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Sustainability becomes a major topic

The shipping sector is facing major challenges due to new regulatory requirements and sense of awareness for sustainable business. Ship operators need to reduce their impact on climate and water quality while at the same time managing a strong increase in demand of goods transported. They are balancing competing objectives in profitability, cost effectiveness, and environmental sustainability. The maritime industry is making large investments in higher efficiency through vessel size and design. They are also looking for an optimisation of technologies used. Considerable potential for optimisation can be found in a vessel's various propulsion systems such as thrusters and propellers and their lubrication.

In addition, global and territorial environmental legal requirements have to be met. These include emission targets, ballast water management and prevention of oil pollution discharges. Important to global shipping is the current US Vessel General Permit (VGP) and the future Vessel Incidental Discharging Act (VIDA) stipulating that all ships passing through US waters must manage their operational discharges of pollution. Among the categories included is the mandatory use of Environmentally Acceptable Lubricants (EALs) at all water-lubricant interfaces. This is due to the fact that during normal operation, as well as through accidents, lubricating oil can leak into the seas, putting at risk both human health and the environment. EALs are therefore a significant contribution to preventing marine pollution.

Unfortunately, as has become evident, high performance capacity and good environmental compatibility are often opposing goals in a lubricant. Very often commercially available EALs show considerably lower performance than mineral oil-based lubricants depending on their design and chemistry. This can include a lower oil film thickness to separate the propeller shaft from the propeller bearing, a lower compatibility of the EAL with elastomers used in propeller shaft seals and/or the chemical stability of the EAL with water. Such weaker performance in comparison to a mineral stern tube oil can lead to equipment damage or more frequent oil change intervals. Furthermore, there exists an interdependence between the performance of lubricants and the applications they are used for. Propeller shaft seals and journal bearings were designed with mineral oils in mind. Changing over from a commonly used mineral oil to an EAL may have far-reaching consequences on the tribological system as a whole if the EAL does not show the same performance as mineral oils.

On the way to a clean future in shipping

Klüber Lubrication is one of the first lubricant makers to conduct research and development in the field of readily biodegradable lubricants that are non-toxic and meet the tribological performance for lubrication of propeller shafts and thrusters. Between 2006 and 2013 Klüber Lubrication developed market-leading EALs for stern tubes (Klüberbio RM 2 series) and thrusters (gear oils, Klüberbio EG 2 series) based on ester oil technology. Both oil series are benchmarks for ester oil based EALs and gained approvals from all leading propeller equipment and thruster manufacturers.

A primary goal in the development of a new type of EALs has been to maintain the advantages of their ester based lubricants while extending oil change intervals to line up with a typical five-year dry docking schedule. Klüber Lubrication's first product based on the new technology is a stern tube lubricant conforming to VGP requirements and offering similar or better performance characteristics as a mineral oil-based lubricant. This innovation is the much longed-for quantum leap in the lubrication of ship propulsion systems – a vital prerequisite for a clean future in shipping. The new stern tube oil was recently launched under the name **Klüberbio RM 8-100**.

The problem with EALs under high loads

For the lubrication of the propeller shaft running in the stern tube and propeller shaft seals, the VGP stipulates the use of EALs for the protection of the environment as an escape of oil into the sea through the propeller seal cannot be completely prevented. Biodegradable lubricants for stern tube application from several suppliers have been available for nearly two decades. So far, however, no one has succeeded in offering an EAL with a performance capacity equalling that of a mineral oil-based product in all important performance criteria such as a strong lubricating oil film, consistency at the presence of water in the oil and excellent seal compatibility.

Why can an insufficiently strong oil film be a problem? Under particularly high loads, for example during voyages with partially immersed propeller or at hard manoeuvrings, insufficient strength of a lubricant film can lead to metal-on-metal contact and higher journal bearing temperatures eventually causing bearing damage. Many commercially available EALs show insufficient resistance to oxidation and hydrolysis as well as poor lubricating capacity under high loads. Excessive shear loads may cause them to lose their viscosity and hence their ability to form a load-bearing lubricant film. High oxidation and ageing can cause their viscosity to increase in an undesirable way. Chemical processes and the presence of water tend to decompose the lubricant. A failure of components and possibly even a breakdown of the propulsion system are possible. Frequent oil changes are therefore inevitable with some commercially available EALs, leading to additional operating costs.

An additional challenge in propeller shaft lubrication is that not only does lubricant leak into the water, but, vice versa: The lubricant becomes contaminated with water via the same path. The insufficient resistance to hydrolysis of most commercially available ester oil based EALs results in a rising TAN (Total Acid Number), leading to an unscheduled complete or partial oil change and a shorter service life of the seal in the stern tube. The only way to prevent early oil changes due to a rising TAN has so far been the installation of expensive filter systems and oil dryers. This, however, constitutes a major investment and increases complexity on board.

Eco-compatibility vs. performance

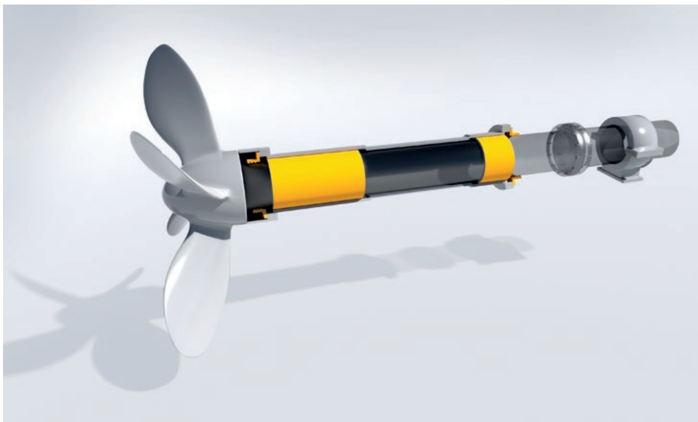
The objective of developing Klüberbio RM 8-100 was to obtain a stern tube oil that is not susceptible to hydrolysis, extends service life in comparison to conventional EALs and meets all sustainability requirements of the EU Ecolabel and the current VPG and future VIDA for operation of ships in the US.

Besides proven biological eco-compatibility, the new product was designed to achieve excellent performance in terms of compatibility with seals, shear stability, wear behaviour, corrosion protection and friction. While the lubricant films formed by some EALs found in the market are not thick enough to prevent damage to stern tube bearings under unfavourable load conditions, the new product is designed to build up a load-bearing film that is close to that of a mineral oil-based product.

In brief: The role of the stern tube

All types of vessels, whether container ships, bulk carriers, harbour tugs or cruise liners, have one thing in common: propulsion is by means of large propellers of varying design. With few exceptions, the shafts of fixed-pitch and controllable-pitch propellers run in journal bearings mounted inside the stern tube filled with oil. The radial movements of the propeller shaft in the bearing are larger than those of other industrial shafts and may be intensified by the force of waves or vibrations.

Radial shaft seals or mechanical seals prevent the oil from leaking into the sea and also keep the stern tube tight against the engine compartment. Thrusters are filled with gear oil and also have to be sealed at the propeller shaft as well as at the rotating steering shaft of azimuthing thrusters to prevent leakage into the water. It is, however, not possible to seal the stern tube or the thruster 100 % tight against exiting oil.



Typical arrangement of propeller shaft, bearings and seals in a stern tube

EALs under test

Two classes of oil can be considered as base oils for EALs: Synthetic oils or oils obtained from vegetable or animal fats. While natural based oils are biodegradable, they have characteristics which make them unsuitable for high-performance lubrication. Only by combining synthetic technology and biodegradability can one create lubricants which perform at the highest level that are environmentally safe.

Typically, a stern tube lubricant has to meet several requirements. Just to name a few: Oil film thickness ensuring hydrodynamic lubrication, good load carrying capacity, good seal compatibility, resistance against scoring/wear, shear stability, oxidation stability, hydrolytic stability, biodegradability, low toxicity, etc. Conventionally, mineral oils have been dominating the marine market due to their price advantages and availability, but the downside is their toxicity and poor biodegradability. This is where EALs score better than mineral oils. So far there have been quite a number of EALs commercially available in the market which claim to be suitable for the lubrication of stern tubes. Within the synthetic family, several different types of chemistries exist, but the one most widely promoted in the market is the ester based EAL. It has been a question of debate whether all these EALs deliver similar performance (say, for the same viscosity grade VG 100) or if they behave disparately.

This question was taken up by the DNV GL, a world-leading internationally accredited registrar and classification society.* Their laboratory study shows specific characteristics where EALs not only differ from mineral oils but also among each other. These properties affect the safety margin of the aft stern tube bearing under certain critical operating conditions and can cause potentially massive failures in stern tube bearings. The chemical and design concept of each individual EAL product determines the degree of safety in the application.

To illustrate the relative stability of oils in the presence of water, the Beverage Bottle test according to the test norm ASTM D 2619 is a suitable method. Hydrolytically unstable oils form acid as a product of chemical reaction of ester oils and water, which causes corrosion in a stern tube system or leads to incompatibility of the stern tube oil with the elastomer materials of the propeller shaft seals. The acid content in an oil can be measured by a titration with KOH. The result of such a titration is the TAN (unit: mg KOH/g oil).

From all tests of ester-based EALs, Klüberbio RM 8-100 shows by far the best test result and nearly no increase of the TAN while at the same time an adequate oil film thickness is retained (see graphic below). This test result proves that the oil is very stable in the presence of water, even similar to the stability of a mineral oil based stern tube oil.

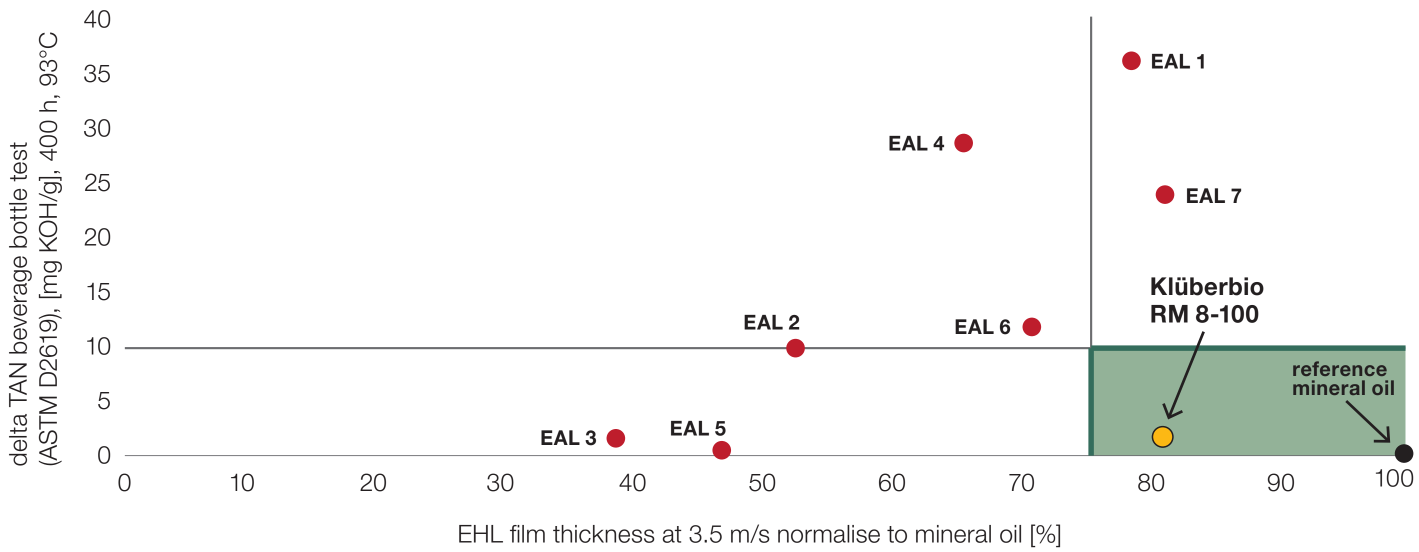
Another important property a stern tube oil should hold is its ability to form an adequate lubricating film under dynamic conditions. This is particularly important as synthetic lubricants generally possess a lower pressure-viscosity coefficient than the mineral oil of same viscosity grade, resulting in a thinner lubricating film. Furthermore, shear stability of lubricants plays a vital role in ensuring the required viscosity even at high shear rates. Therefore, lubricant performance in hydrodynamically lubricated contacts, as in a propeller journal bearing, depends strongly on the properties of the lubricant in use. It is important for a stern tube oil to completely separate the propeller shaft from the bearing by adequate lubricant film formation even at high loads. This would provide a higher safety margin under extreme load conditions, e.g. during manoeuvring of the vessel, and will prevent metal-to-metal contact of propeller shaft and journal bearings. A well optimised EAL with good hydrodynamic oil film properties will not encounter overheating of journal bearings or bearing damage as experienced with some inferior EALs under stressful installation and operating conditions.

EAL stern tube oils based on synthetic ester oils or polyalphaolefin oils (PAO) can have significantly different hydrodynamic film forming characteristics, depending on the base oils and long chain polymers used in the lubrication formulation. Especially when base oils with a low kinematic viscosity are used in combination with polymers to increase the overall lubricant viscosity to the requested ISO VG 100 or 150 viscosity grade.

With the use of the EHD rig from PCS Instruments, the lubricant film forming properties of different oils in an EHL (elastohydrodynamic lubrication) contact can be compared. Under the conditions investigated in our study, Klüberbio RM 8-100 shows a thick film formation compared to other available EALs. The results of the study highlights the fact that other EALs do not deliver the intended high performance. Thus, lubricant selection has to be made cautiously in order to avoid stern tube bearing damage.

* DNV GL, Environmentally Acceptable Lubricants show reduced capabilities under certain conditions, Technical and Regulatory News No. 15/2019

Scatter plot chart – EHL film thickness vs. delta TAN



Next generation of EAL lubricants

The newly developed Klüberbio RM 8-100 successfully meets maximum environmental as well as performance requirements. Klüberbio RM 8-100 generates a lubricant film of excellent thickness that persists even under high edge loads in the propeller shaft bearing. Due to this lubricant film, the propeller bearing and the shaft remain separated and overheating of or damage to the bearing is prevented. Klüberbio RM 8-100 shows very good compatibility with the elastomer material in the propeller shaft seal, providing it with optimal lubrication. This ensures a long service life and full function of the components.

Regarding TAN and resistance to hydrolysis, the new product's performance ratings are multiples of those of ester-based EAL stern tube oils - almost up to the standard of mineral oil-based lubricants. This means the oil's chemical composition prevents it from reacting with water getting into the stern tube through the elastomer seal. The TAN hardly rises, leading to a significantly longer life expectancy for both the propeller shaft seal and the oil.

Klüberbio RM 8-100 is the first lubricant based on a new technology. Klüber Lubrication will adopt this new technology also into its range of EAL gear oils designed for tunnel and azimuthing thrusters.

Two worlds come together

Klüber Lubrication already showed in the past that bio in a lubricant no longer stands for a compromise of a product being green, but having weaker technical performance. With our new generation of Klüberbio stern tube and gear oils, we have excellent lubricant performance, often considerably better than the direct mineral oil based competition, and the products are also biodegradable and non-toxic.

With Klüberbio RM 8-100 users obtain a technology-leading product meeting legal environmental requirements and offering at the same time the extremely good performance ratings of a conventional, mineral oil based lubricant. This is important in particular for international shipping operations, where sustainable approaches are increasingly required.

In brief: VPG and EALs

While most of these individual leakages are small, the increase in shipping movements means this constitutes a growing problem for the environment. Mineral oils containing additives are slow to be decomposed by the microorganisms in the sea water. The hydrocarbons and additives contained in mineral oil products in particular can be toxic for marine life.

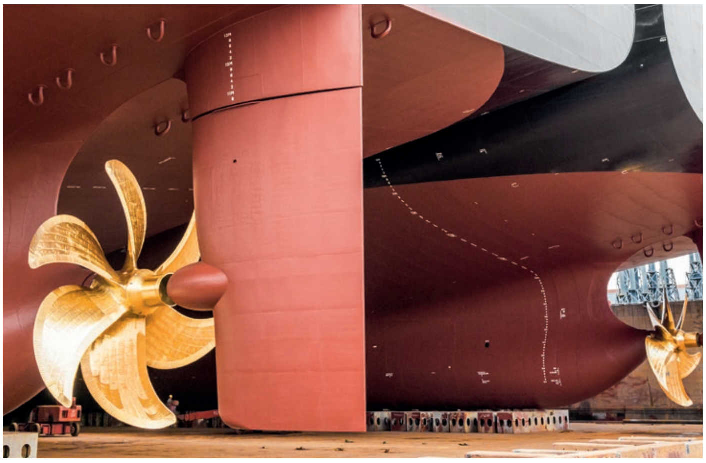
To limit the harmful leakage of lubricants and other media, the USA issued the Vessel General Permit (VGP), which came into force in 2013. The VGP will be replaced by the new Vessel Incidental Discharging Act (VIDA). Standard lubricants based on mineral oil are only permitted in exceptional cases for lubrication of propellers, thrusters and other equipment with water-lubricant interfaces. The only permitted lubricants are those placed on the market as Environmental Acceptable Lubricants (EALs). They must have the following characteristics:

– Non-bioaccumulative: the chemicals may not accumulate in the tissue of an organism and enter the food chain

– Biodegradable: the constituent substances of a lubricant must naturally break down at least 60 % of the formulation within 28 days

– Non-toxic to aquatic life: The lubricant must not hinder the growth or well-being of aquatic life

This shows the criteria determining what makes an EAL relate to the consequences of lubricant leakage on the water and its microorganisms. Bioaccumulation describes the degree to which a chemical can build up in a living organism; biodegradability is the timespan during which a lubricant will decompose into harmless components. Minimally toxic lubricants have no or only a very small impact on marine organisms.



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Klüber Lubrication München SE & Co. KG
Geisenhausenerstraße 7, 81379 München, Germany
Certificate of registration 46624
www.klueber.com