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"The greatest possible freedom of design requires large amounts of energy"

Operating supplies such as oils and greases have not yet fallen under the lens of defossilization measures. Yet these products, which are currently manufactured from fossil crude oil, are also required in vehicles that purport to be emissions-neutral. Bernhard Hagemann, Head of Innovation Management and New Markets at Fuchs Schmierstoffe, explains the challenges and opportunities associated with friction optimization and defossilization.

MTZ _ Is defossilization of lubricants possible as it is with fuels?

HAGEMANN _ Yes, it is, although it's not easy. Renewable lubricants, that is to say biogenic or recycled lubricants, are already used for many different applications, from hydraulic oil to cooling lubricant and chainsaw oil. Transmission and engine oils are also available, such as in agricultural technology or for construction machines. Yet the tough requirements for performance and efficiency in

Bernhard Hagemann (born 1968) studied mechanical engineering after a professional education in communication technology and started his career as a development engineer for NVH optimization of cars with combustion engines. He then moved to the German Engineering Federation (VDMA) as an advisor and networker for drive technology. In 2007, Hagemann joined the management of the Research Association for Drive Technology FVA and established E-Motive, a new platform of FVA and FVV for joint research and communication on electric drive systems for vehicles and mobile machines. In 2017, Hagemann joined Fuchs Schmierstoffe GmbH and coordinated the transformation and e-mobility activities. In April 2021, he was appointed Head of Innovation Management and New Markets.

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the automotive industry, combined with the need for the greatest possible cost efficiency pose a challenge for us. We have stable value chains in the mineral oil industry that have become established over many years, the highest standards, and reliable quality. As such, the low-cost availability of high-grade base oils and high-performance additives from fossil sources were what decided competitiveness in the past. Now, however, ecological sustainability and the carbon footprint are increasingly seen as make-or-break aspects alongside price and performance. Bio-based oils and greases, preferably from plant sources but also of animal origin, are stepping to the fore. Alongside established esters made from plant oil, there are many possibilities for manufacturing lubricants from renewable raw materials, each with their own advantages and disadvantages. Yet renewable raw materials represent only part of the solution: The circular economy attempts to combine economic, technical, and ecological aspects in intelligent application cascades. In terms of lubricants, this means that we are making efforts to increase the use of re-refined lubricants for certain applications, but also to find new approaches to lubricant regeneration directly on the machines, on the lubricated system. If we look at the goal of carbon neutrality, it is clear that alternatives need to be established to the use of crude oil as a base product. This will be a gargantuan task and not everything can be taken directly from biogenic sources. Quite simply, the use of renewable raw materials must not compete with the production of food and feed, otherwise this would cause secondary global effects like increased land use, eutrophication, etc. to fill the gap. In the future then, a particular opportunity will lie in the energy-efficient, higher-grade processing of used materials and waste products. We are researching these topics very intensively. In the "ZeroCarb Footprint" research project, for example, we have succeeded in selecting substances contained in used deep-frying fat using gentle, enzymatic methods and converting them into lubricant components – in effect refining them. There are countless other sources for producing lubricants from renewable origins. Household or commercial waste, sewage sludge – things which in the past had to be laboriously disposed of have the potential to become sources of raw materials in the future. Seen from a purely technical perspective, it is possible to produce lubricant components from CO_2, however this requires a huge amount of energy. If wind and solar energy were unable to be put to other use at a particular time, this excess electricity could even generate a negative carbon balance In the context of the Rheticus research project, we are collaborating with Evonik to produce lubricant components derived from CO_2 via artificial photosynthesis and downstream biocatalytic conversion. The key to such approaches will always be the availability of green energy – if we look at it another way, this is a method of storing excess energy in processes.

"Synthetic lubricants from biogenic sources are available"

Are there already systems in place for producing non-fossil lubricants?
Yes, synthetic lubricants from biogenic sources are available, although not in the quantities and at prices that would allow large-scale use, such as in the automotive industry. The most well-known of these is of course biodiesel production – the methyl esters this produces could also form the basis for lubricants. With the efforts to find alternative fuels and pursue recycling, we too are taking giant steps into a fossil-free future. This trend is a special opportunity for us at Fuchs. As an independent lubricant producer, we are free to choose our sources on the market for renewable raw materials. We are working hard on sustainable solutions, which draw on the preparatory work of nature for maximum product efficiency – we want to lead the field in this area. Outside of the automotive industry, we are already the lubricant producer with the largest range of biogenic products – you can find a technically compatible bio-lubricant for many applications, from chainsaw oil to engine oil. We are pleased to lend our experience in non-automotive sectors to developments in the automotive industry.

Do these oils offer greater freedom of design in their lubricant properties than those of fossil origin?
The advantages of synthetic base oils are well-known. Yet, it doesn't actually make any difference where the hydrocarbon chains come from here. Today, they are generally broken down to the base components of ethylene and propylene first in order to then reconstruct the diverse world of chemistry from there. Theoretically, this offers the greatest possible freedom of design, but it requires large amounts of energy. Step by step, we are seeking ways to make the best possible use of nature's synthesis input – this can be plant oils as well as cellulose, lignin, sugar, and much more. There are of course particular rules for the lubrication-based adaptation of these "new" raw materials – the freedom of design must be balanced against the energy consumption required for chemical conversion.

Are the additives we are familiar with in oil still necessary or can the base oil be equipped with improved properties?
I can answer both parts of that question with yes. It will never be possible to go without additives completely. However, many biogenic raw materials really are functional base oils, meaning that compared to pure hydrocarbons, the parts which have a chemical function and contain oxygen have several advantages in terms of application. For example, they reduce friction and wear, which means we can reduce special additives accordingly under certain circumstances. However, it is currently still difficult to defossilize these additives. These special chemicals cannot easily be replaced, merely reduced. Yet, we are currently working on a completely new generation of lubricants which are far superior to conventional oils in a transmission in terms of reducing friction and heat transfer. These fluids contain considerable amounts of water. But this kind of thing isn't simply a drop-in solution. Instead, the transmission needs to be designed to follow the particular properties of the new superlubricant – in return, the possibilities for saving energy are in another dimension entirely. We have a whole series of ongoing projects in this field with technological leaders in the automotive industry.


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"We are working hard on sustainable solutions, which draw on the preparatory work of nature for maximum product efficiency", Hagemann says

Does this have an impact on the recycling properties? Are non-fossil oils easier to reuse?
Partly. Design for recyclability is generally possible for lubricants, it just hasn't been a priority until now. But that changes now. We give it particular attention in our research projects. In our water-based transmission lubricant prototypes, for example, the water can be separated out relatively easily. In the future, recycling will generally be mandatory, also for bio-based lubricants. The lubricant of the future must not be burnt at the end of its service life. There is no other reasonable way to achieve a sustainable, carbon-neutral world. One fundamental problem when recycling lubricants is unfortunately the controlled collection of used oil – collection by type poses logistical difficulties and recycling mixtures of unknown or inconsistent quality automatically reduces the quality of the product and process efficiency. As a result, recovering base oils requires very involved processes – filtration, distillation, hydration. This means that recycling is not usually economical and the used oils are gratefully received for thermal utilization. If we were to succeed with separating and collecting used products, recycling could also take a far more specific approach.

As a lubricant producer, can you identify any other ways of improving the sustainability of lubricated systems?
Alongside using sustainable raw materials and additives and optimizing production processes, lubricants play a part in extending the service life of vehicles, machines, or systems. New machines cost money and a lot of energy until they can be considered a replacement for "used" systems. The right lubricant helps to reduce wear and prevent corrosion. In this respect, extending the useful life of investments made is also a sustainable purpose of lubricants. However, the most important contribution to sustainability is probably friction reduction or increasing energy efficiency. That is why reducing loss is a constant optimization goal. Rheological losses must

also be avoided here, which is why we continuously reduce viscosity and are also searching for further possibilities to reduce loss.

How much further can viscosity be reduced? Does it even make sense to make the viscosity as low as possible, or does this increase the risk of leaks from low viscosities?
We're already at a very low level and the effort involved not just in sealing is beginning to increase. A fundamental change to the system seems the more sensible option. That's why we are pursuing the approach with water-based transmission fluids, which have extremely low steel-steel friction values and also cool very efficiently – a property which is in demand, particularly for e-axles. In one project we were able to achieve efficiency of over 99 % at certain load points in an e-drive transmission with such a prototype.

Are there different requirements for the oil used in single-gear and multi-gear transmissions in electric vehicles?
Yes, because multi-gear e-drives employ shifting elements such as friction clutches. In these cases, the lubricant also has a significant role to play in controlling the friction coefficient and has to offer additional properties. Our many years of experience in dual clutch transmissions have been of use to us in this respect in a prominent e-drive project with a sports car producer. Plus, we keep the electrical requirements in mind, as many e-drives pose completely new challenges to compatibility with electrical or electronic components.

Can you explain what you mean by that? How has your work changed with the increasing trend toward e-mobility?
Alongside the usual chemical and mechanical properties of the lubricants, electrical properties are now required, too, such as electrical conductivity or dielectric strength to voltage. We also need to develop new testing methods. Each customer had very different requirements in that respect. Thanks to the sector's collaboration in precompetitive research associations, we can address these issues together and develop standards. We've already come a long way as things stand today.

"It will never be possible to go without additives completely"

In hydrogen combustion engines, the blow-by of oil in the combustion chamber is one of the main sources of carbon emissions. What kind of challenge does the gas pose for the lubricant used and how can this be addressed?
The combustion of hydrogen will pose challenges as well as offer opportunities as regards lubricant formulas. Special attention will need to be given to its high flammability, for example, and hydrogen's tendency to pre-ignite. Yet this can be positively influenced by using suitable oil chemistry. The compatibility and interaction of the engine oil with the combustion product of water will also have an influence on future oil technology. The residual CO_2 emissions generated in the co-combustion of conventional engine oils can be significantly reduced again by using low-carbon base oils and additives or such products originating from renewable sources.

Would lubricants have to be adapted for the use of alternative liquid fuels in combustion engines, even though the applicable standards are being met?
That depends on the type of alternative fuel. The Fischer-Tropsch fuels are especially compatible in this respect, although there are differences regarding solubility and polarity. It will be possible to use the common alcohols like methanol and ethanol with some adaptations. When using exclusively the latter, attention will need to be given to aspects such as how condensation is dealt with and the associated effects on corrosion and flowability. Fortunately, there is a great deal of experience in this area in regions like South America from the series operation of bio-based alcohols in high concentrations.

The combustion behavior of methanol increases stress on the engine and the fuel causes seals to become brittle. Can this effect also be countered by oil formulas?
Increased thermal load on the oil can be countered effectively by using today's synthetic base oils in connection with suitable additives. Fuchs has broad experience in this area. The embrittlement of certain seal materials can also be influenced by the oil formula. With particularly high loads, more robust polymers could be considered here in combination with suitable oils. This makes it possible to achieve very good operational reliability. However, the greatest challenge is this: If fuels become renewable, lubricants will have to be too. The first synthetic base oils of outstanding quality created from renewable raw materials can already be found on the market and are also being tested for use in engine oils. However, there is still a lot of work to be done to make them available in large quantities with consistent quality around the world.

Bernhard Hagemann, thank you very much for this very interesting interview.

INTERVIEW: Marc Ziegler