Effects of Efficient Greases on the Operating Range of BEVs

The use of lubricating greases in hybrid (HEV) or fully electrified passenger cars (BEV) may have a positive impact on their operating range. Here, Fuchs Schmierstoffe explains the prioritization of individual vehicle components for the topic friction minimization, the advantages of efficient greases as well as the special demands electrified vehicles impose on these automotive fluid class.

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In order to be able to classify individual greased components in Battery Electric Vehicles (BEVs) or Hybrid Electric Vehicles (HEVs), Fuchs Schmierstoffe carried out an analysis and assigned priorities based on degrees of efficacy relevance. They are defined by the duration of the power supply to the individual components from the vehicle's battery. The longer a component taps into the battery energy, the higher the electricity consumption.

An efficient or in other words low friction lubrication can improve the degree of effectiveness, thus reduce the energy demand and therefore make an important contribution to the extension of the vehicle's operating range. Consequently, components that consume more electricity also have a greater operating range boosting potential as a result of increased efficiency. Three efficiency degree relevant priorities generated by optimized grease lubrication were defined which are presented in the next paragraphs.

FIRST PRIORITY: DRIVE TRAIN

Components that are either parts of the drive trains or directly connected to it are allocated to drive train priorities. While the vehicle is in operation, they take on the role of constant direct or indirect automotive battery electricity consumers. Among the first priorities considered are for instance the greased bearings in the traction electric motor, the wheel bearings or the joint shafts. The potential energy savings of these components as a result of the increased degree of effectiveness are high, since their operation utilizes the largest share of the battery supplied energy. Consequently, a boost of these component efficiencies has the potential of delivering the largest operating range extension. Currently, the focus in the development of low friction greases is on first priority components.

SECOND PRIORITY: PERMANENTLY SERVO-ACTUATION SUPPORTING COMPONENTS

The second priority comprises components that also continuously embedded into the operation of the vehicle, while assuming supporting roles only. Among these are, for example, the steering system, the brake booster, or the cooler fan. The optimized degree of effectiveness of these components, which can be achieved if low friction greases are utilized, does not have as strong of an impact on the vehicle's operating range as a first priority improvement of the drive train. However, these components most certainly offer potentials for energy savings, too.

THIRD PRIORITY: TEMPORARILY SERVO-ACTUATION SUPPORTING COMPONENTS

Components that are only used for a limited period of time and thus tap into the vehicle battery's energy supply merely temporarily, are categorized as third priority components. This category includes, for instance, the parking brake or the seat adjustment. Given that these parts are only temporary electricity consumers, their operating range extension potential is much smaller than that of the other two priorities. Nonetheless, even third priority components do have the capability to have a positive impact on the passenger car's operating range if efficient greases are used. This objective is primarily attained through synthetic greases, which deliver reduced breakaway and driving torques even in low temperature conditions (up to -40 °C) and thus demand a lower electrical deployment output.

EVALUATION AND ADVANTAGES OF DEGREE OF EFFECTIVENESS RELEVANT PRIORITIES

The described categorization into the three designated priorities translates into a focused evaluation of the lubricant applications in HEVs and BEVs. **TABLE 1** allocates the greased automotive components to these three priorities.

The friction minimization of grease lubrications can be achieved through a low base oil viscosity as well as special, optimized thickeners and additive technologies. The reducing friction is of particular importance primarily for the degree-of-effectiveness-relevant first priority components. The vehicle's electricity consumption can be reduced thanks to the decreased power losses in the drive train, which can also be attributed to the lower friction in these components. Among other things, the coefficient of friction μ describes the interior friction of the lubricant that has a significant impact on the degree of effectiveness of the components in the hydrodynamic lubrication area.

The development of efficient greases mandates the precise measurement of the grease dependent friction in model and component test stands under load conditions that are as actual application proximate as possible. One available option is the so-called Mini Traction Machine (MTM) from PCS Instruments. **FIGURE 1** includes the measuring results of an MTM test run and clearly identifies the difference in the friction patterns of a standard and a friction-optimized wheel bearing grease. It is clear that the coefficient of friction of the optimized grease has been reduced by 50 % compared with the standard wheel bearing grease (μ = 0.015 instead of 0.030) and thus a positive influence can be exerted on the efficiency of the component.

In most cases, low friction greases are formulated with thin base oil viscosities. However, this may result in the premature failure of rolling bearings due to wear and fatigue. To counter act this effect, it is essential to make sophisticated choices as far as the base oil types and lubricant additives are concerned. Fuchs Schmierstoffe has at its disposal a modified FE8 test bench (basis according to DIN 51819) that enables the company to test the fatigue-related lifetime of rolling bearings under critical load and rotational speed conditions. The bearing is vibration monitored during this process and the test is aborted if the defined limits are surpassed. Consequently, it is possible to assess whether the grease has the potential of reducing the likelihood of a premature bearing failure due to wear and fatigue.

Besides the capability to reduce friction, efficient greases have additional properties that have a potentially positive impact on the operating range of a BEV or HEV. For instance, the specific stress

First priority	Seco nd priority	Third priority
Traction electric motor	Steering system	Parking brake
Wheel bearing	Brake booster	Seat adjustment
Joint shaft	Cooler fan	Steering column height adjustment
Propel shaft	Brake caliper	Mirror adjustment
Wheel hub motor	Electric-mechanical brake	Door lock
Dual mass flywheel*	Synthetic gearbox	Window lever
–	Wiper blades motor	Sunroof
–	Air conditioner	–

TABLE 1 Grease applications based on priorities and components (*only relevant for HEVs) (© Fuchs Schmierstoffe)

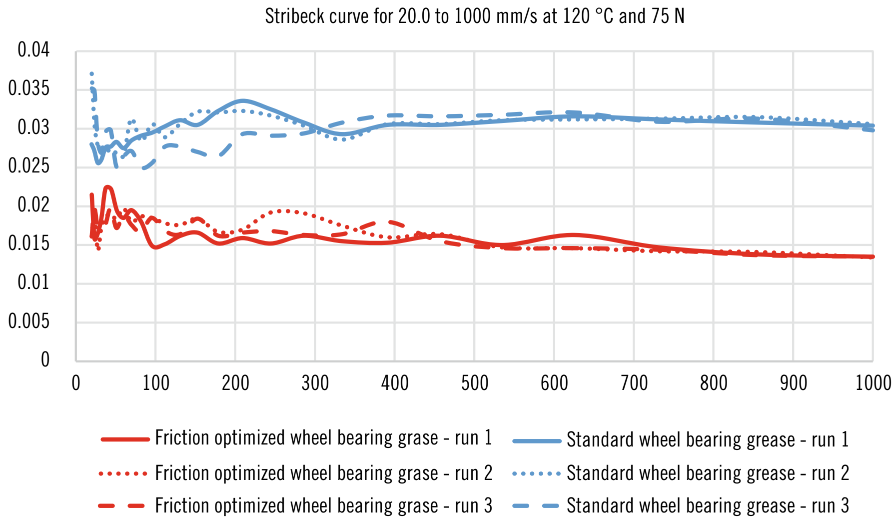


FIGURE 1 Comparison of the Stribeck curves of a friction optimized (red) and a standard wheel bearing grease (blue) – a friction minimization of 50 % becomes possible (© Fuchs Schmierstoffe)

tolerance of a component can be substantially increased. If this factor is already considered during the design phase of the vehicle, it is possible to develop a smaller and lighter component while retaining the same performance levels. The thus achieved weight reduction has the potential of improving the range.

The effect of increased specific stress tolerance applies primarily to first and second priority components. One typical example is the propel shaft. This principle, which is commonly referred to as downsizing, is already in use in innumerable combustion engine models. As described earlier, optimized synthetic greases have the capability of reducing the required electrical current supply. Under the most optimal conditions, this means that electrical lines with smaller diameters can be used, which in turn reduces the vehicle's weight. **FIGURE 2** sums up the described advantages of optimized greases.

A FURTHER REQUIREMENT ON GREASES: PARTICLE PURITY

In addition to the previously described optimization of friction, Fuchs Schmierstoffe imposes three other major requirements on its greases regarding electric mobility. These are low noise, long lifetime of the grease and high rotational speed limits as well as compatibility with electrical current transporting rolling bearings. All of the aforementioned properties can be monitored and evaluated thanks to modern testing procedures. As a result, it is possible to make qualified statements with regard to the suitability of a grease.

The low noise requirement does not simply aim at the reduction of the noise generated by the vehicle component as such, since the noise of the tires in motion and the airstream already eliminate the benefits of "less noisy lubrication" at accelerated velocities [1]. It is far more important that the noise behaviors of greases are primarily impacted by their cleanliness (chemical purity). The mere use of low noise or mechanically highly pure greases translates into a mathematically increased lifetime of rolling bearings [2]. Since low noise greases are free of particles, it is possible to utilize thinner base oils with lower friction rates to improve the degree of effectiveness of the rolling bearings and the tribological pairings without reducing their respective lifetime.

Consequently, Fuchs Schmierstoffe tests the noise behaviors of rolling bearing greases with the BeQuiet+ and MoreQuiet methods. **FIGURE 3** shows excerpts of a MoreQuiet noise test conducted on two greases. Compared with a moderately low-noise grease, the optimized rolling bearing grease exhibits significantly quieter noise behavior, resulting in a better noise class (II/1 instead of II/2).

High rotational speed and temperature compatibility paired with the longest possible lifetime are the key requirements for the grease lubrication of rolling bearings in traction electric motors. Fuchs Schmierstoffe conducts tests for continuous grease utilization on its test benches SKF ROF+ and FAG FE9 at temperatures of up to +180 °C. The rotational speed compatibility and/or the maximum rotational speed limit is determined on the test machine FAG WS 22.

CURRENT-CONDUCTING BEARINGS AND THEIR GREASES

One of the characteristics that has not been examined for greases as thoroughly to date is the suitability for current-conducting rolling bearings. Given the comparatively highly dynamic operation

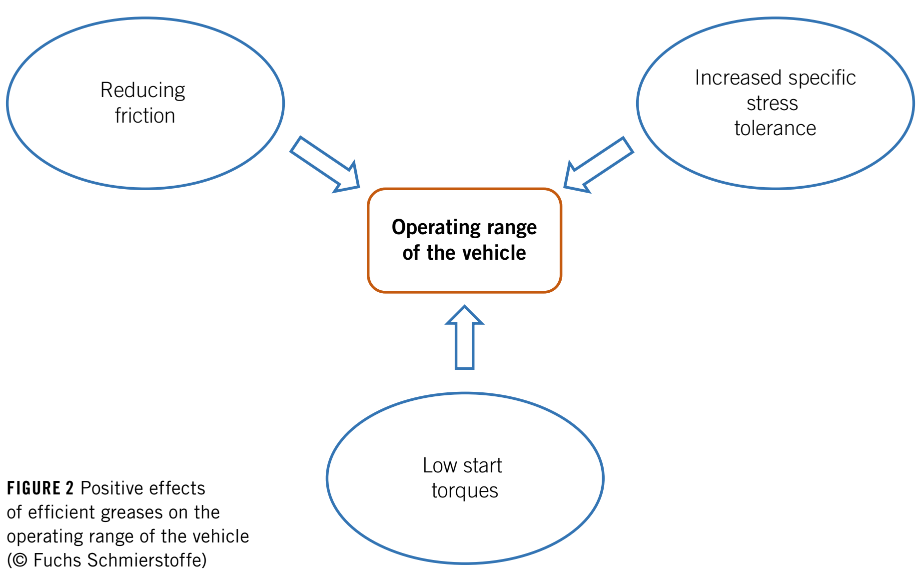


FIGURE 2 Positive effects of efficient greases on the operating range of the vehicle (© Fuchs Schmierstoffe)

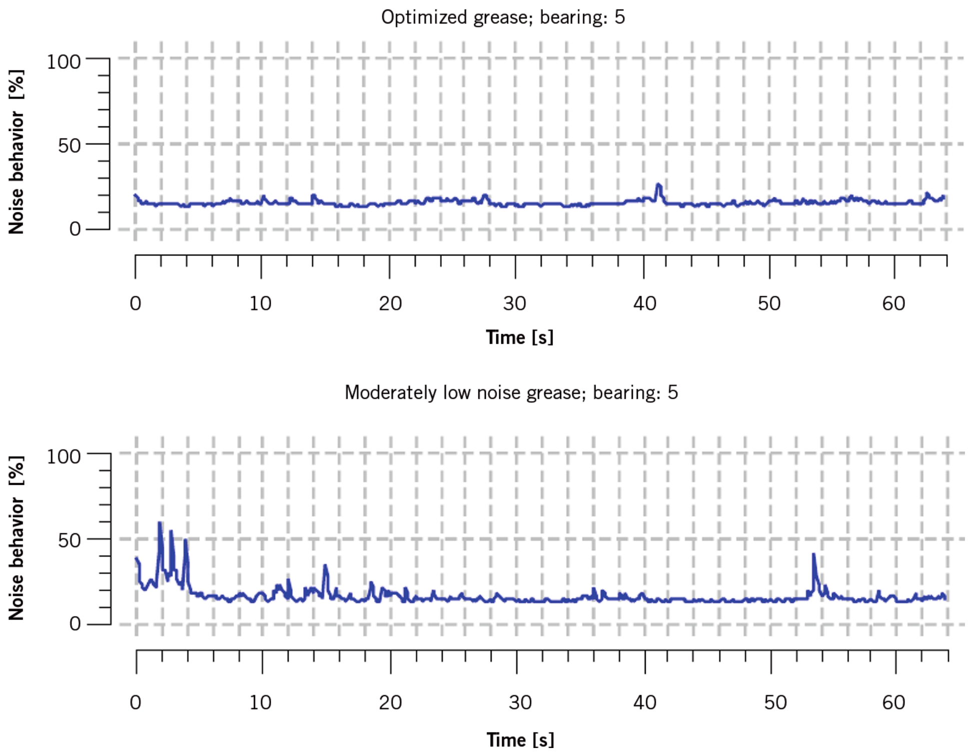


FIGURE 3 Comparison of a noise-optimized (top) and a moderately low noise (bottom) grease (© Fuchs Schmierstoffe)

of frequency controlled traction electric motors, it is, however, becoming increasingly important since in these scenarios, rolling bearings are frequently exposed to damaging currency throughputs and thus are more prone to accelerated wear. Final research into the properties a grease must have to provide sufficient lubrication even under these conditions must yet be conducted. One frequently discussed characteristic in this context is the specific electrical conductivity of the grease, which can for example be influenced through the addition of conductive additives or base oils. The purpose of increasing the electric conductivity of the grease as much as possible is to minimize the electrical throughput energy on the grease and the bearing as effectively as possible. The aim is to prevent damages to lubricant and bearing. Further interdisciplinary research will have to be conducted and time will tell whether this is the proper approach.

Fuchs Schmierstoffe has at its disposal the Dielectro-Rheological Device (DRD) from Anton Paar – a modern testing device that characterizes these electrical properties of fresh and previously used greases. The combination of a rotation rheometer with the measuring set-up of a plate-plate condenser, paired with an impedance spectrometer makes it possible to measure the specific resistance, conductivity and permittivity. The test conditions can be selected randomly across a vast temperature range of -40 to 150 °C and for a frequency range of 20 Hz to 20 MHz. Moreover, the test set-up makes it possible to evaluate greases under shear stress. **TABLE 2** compares the electrical characteristics of a

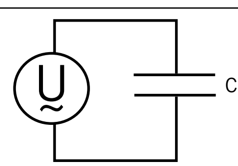
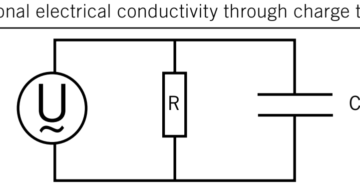
Feature/grease	Conventional grease	Conductive grease
Characteristics	Shows strictly capacitive patterns	Ohm patterns at low frequencies Capacitive patterns at higher frequencies Additional electrical conductivity through charge transport
Comparable substitute diagram	 	
Formula for impedance	$\lvert Z\rvert = \frac{1}{\omega C} = \frac{1}{2\Pi f \varepsilon_r C_0}$ $\varphi = -90°$	$\frac{1}{\lvert Z\rvert^2} = \frac{1}{(\frac{1}{\omega C})^2} + \frac{1}{R^2} = (2\Pi f \varepsilon_r C_0)^2 + \frac{1}{R^2}$ $\varphi = 0°$

TABLE 2 Comparison of a conventional grease with an electrically conductive grease regarding their impedance *Z* (© Fuchs Schmierstoffe)

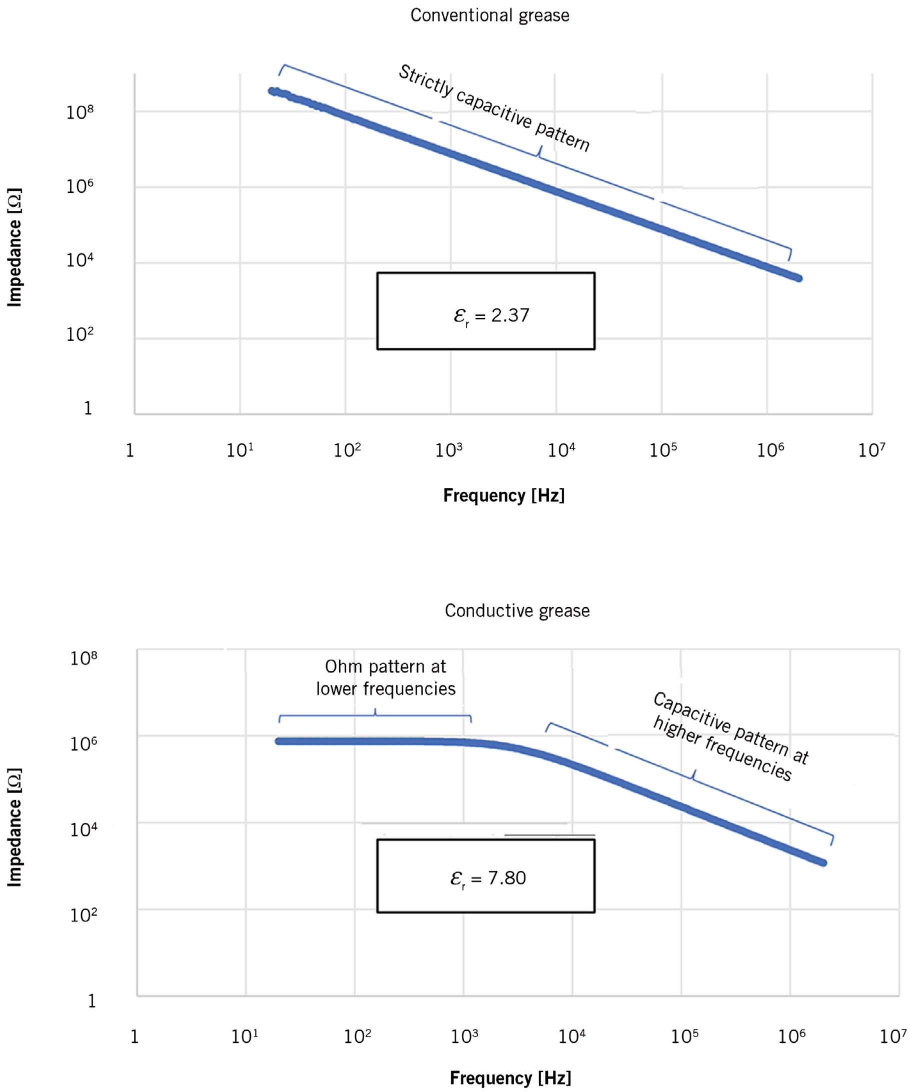


FIGURE 4 Impedance curve and permittivity value ε_r of a conventional (top) and a conductive (bottom) grease at a rotation frequency of 20 Hz to 2 MHz (© Fuchs Schmierstoffe)

conventional grease and an electrically conductive grease, while **FIGURE 4** shows the impedance curves of them.

CONCLUSIONS

The electric mobility requirements imposed upon the utilized greases are not new. However, their prioritization has changed. The focus has further shifted in favor of the reducing friction and the related increase of the degree of effectiveness. The importance of low-noise performance as well as compatibility with current-conducting rolling bearings continues to grow as well. If companies take these requirements into account when they develop efficient greases, they can have a notable positive impact on the operating range of electric vehicles.

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