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Guest Editorial

Special Issue: Electric Vehicle Tribology

The development of electric vehicle (EV) technology has evolved rapidly over the past few decades, with significant improvements in performance and efficiency. Among the most vital yet often overlooked aspects of EVs are the lubricants and materials used in their powertrains/drivelines. The role of lubricants and materials in EVs is multifaceted, as they directly impact component life, vehicle efficiency, energy conservation, and the overall driving experience. Despite advancements, challenges remain, especially in the field of lubrication under harsh thermal and electrical conditions. This special issue contains 15 papers disseminating some of the most recent advancements in the key areas of EV lubricants, testing, advancements, and the unique demands these vehicles place on lubrication technologies. Although each of the papers has its own merits, together they emphasize the need for a better understanding of tribo-electric contacts, lubricants, and materials that can adapt to the changing wear mechanisms, offering protection across a range of operational conditions. As the performance demands of electric motors and drivetrains continue to evolve, lubricant technology must also advance to meet these needs.

Lubricants, including greases and oils, are crucial for reducing friction, wear, and heat generation in the components of EVs. They help ensure smooth operation, increase the lifespan of moving parts, and improve the overall energy efficiency of the vehicle. In the case of EVs, the lubrication system faces unique challenges compared to traditional internal combustion engine (ICE) vehicles. The high torque, immediate power delivery, and rapid acceleration inherent to EVs put additional stress on components such as bearings and gears, requiring more advanced lubrication solutions to maintain performance. In addition, the high speeds and temperatures in EV drivetrains, along with exposure to electrical currents in bearings and gears, necessitate specialized lubricants, materials, and coatings. Unlike conventional ICE vehicles, where lubricants are primarily tasked with handling mechanical stresses, EV lubricants must also contend with the risk of electrical damage, such as electrical pitting and erosion in bearings and gears, and increased temperature as well. Therefore, designing new lubricants that can endure both mechanical and electrical stresses while maintaining stability and performance is a complex and ongoing challenge for engineers.

Some of the recent advancements in lubricant technology for EVs presented in this special issue have focused on enhancing base oils and incorporating cutting-edge additives to address the unique requirements of EV powertrains. One notable development is the use of advanced material additives, such as carbon, iron-oxide, silver, boron nitride, and ionic liquids. These additives help improve the lubricant's thermal stability, reduce friction, and protect against electrical damage. Graphene, for instance, is known for its excellent conductivity and strength, which may make it a valuable additive in reducing wear and enhancing the overall durability of EV drivetrains. In addition to additives, the selection of base oils is highlighted as critical to achieving the desired lubricant performance. Polyalphaolefins (PAOs) are commonly used as base stocks in synthetic lubricants due to their excellent thermal and oxidative stability. By combining PAO with the right additives, engineers can create tailored lubricants that optimize performance and efficiency under the demanding conditions of electric drivetrains. Another area of research on the issue is the development of nanolubricants. Nanotechnology has shown promise in enhancing lubrication properties, offering potential breakthroughs in reducing friction and improving the efficiency of various drivetrain components. These advancements not only help improve the lifespan of individual components but also contribute to the broader goals of increasing energy efficiency and reducing maintenance costs in EVs.

The electric axle (E-axle) is a key component in EVs, and the efficiency of its lubrication directly impacts vehicle range and operational costs. Particularly, rolling bearings are vulnerable to electrical damage, such as electrical pitting. Bearings in EVs experience damaging bearing currents due to the use of high-frequency inverters and pulse-width modulation systems in the electric motor. These currents can cause morphological damage on bearing surfaces, leading to premature failure. Part of the research reports presented in this issue demonstrates that selecting and optimizing lubricants for the E-axle can lead to significant improvements in efficiency, which, in turn, enhances battery life and reduces overall energy consumption. This research report underscores the need for bespoke lubricant and material solutions that are customized for the specific demands of each component in the drivetrain. For instance, one study of the issue examined the behavior of polymer gears under varying loads and operating conditions. The results showed that temperature and wear-rates can be significantly impacted by the choice of lubricant, with optimized lubrication helping to reduce friction and wear while improving efficiency. Another paper, as an output of a critical review, emphasized that innovative coatings (i.e., diamond-like carbon), can significantly reduce wear in differential shafts and gears, further highlighting the role of surface treatments in enhancing the durability of EV components. On the other hand, advanced solutions to mitigate the electrification problems in e-axles include the use of inert-gas atmospheres in order to reduce or eradicate the accelerated oxidation triggered by electricity at the contact interfaces. For example, some of the authors showed that, under electrified conditions, the formation of carbon-rich tribofilms and oxidation reduction in dry

nitrogen environments can significantly reduce wear, suggesting that controlled atmospheres could be an effective solution to mitigate most of the damaging effects of electrical currents in dry and lubricated tribo-contacts.

In conclusion, the continued advancement of lubrication technologies is crucial for the ongoing success of electric vehicles. As the performance requirements of EVs expand, particularly in terms of efficiency and reliability, the role of high-performance lubricants and materials becomes even more significant. The research reported in this issue, including the understanding of tribo-electrical contacts, the use of advanced additives, nanotechnology, surface coatings, and advanced lubrication solutions, promises to revolutionize the way lubricants and materials support EV components. As the industry moves toward more sustainable and efficient electric mobility solutions, the development of tailored lubrication technologies will play a pivotal role in optimizing vehicle performance, reducing maintenance costs, and enhancing the overall EV driving experience.

The editors extend our heartfelt gratitude to all the authors from around the world who have contributed to this Special Issue. Your dedication, expertise, and insightful contributions have been invaluable in shaping this collection. It is through your hard work and commitment that we are able to present such a diverse and impactful compilation of cutting-edge research on EV tribology. Your contributions truly enrich the field and inspire further research and innovation.

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