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Development of high-performance e-Axle oil

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This paper reports the development of a high-performance, low-viscosity e-axle oil that simultaneously reduces drivetrain losses and supports oil-cooled motors for electrified vehicles (HEV/BEV). Extending BEV driving range requires improved energy efficiency; however, increasing battery capacity leads to higher cost and weight. The authors therefore focus on lowering frictional losses—especially churning losses in the reduction gearbox—by reducing oil viscosity. In parallel, increasing motor output and power density make thermal management increasingly important, and oil cooling has attracted attention.

However, lowering viscosity introduces trade-offs: a thinner oil film increases the likelihood of metal-to-metal contact in the mixed-lubrication regime, potentially worsening friction, fatigue protection, and anti-seizure performance. Moreover, increasing polar extreme-pressure additives to compensate may reduce electrical insulation (volume resistivity), which is critical for motor oil-cooling applications.

To address these conflicting requirements, the target was set to a market-leading kinematic viscosity of at most 11 mm2/s at 40℃ while maintaining ATF-level or better friction performance, fatigue protection, and anti-seizure performance, together with sufficient electrical insulation. Because e-axles do not employ wet clutches, clutch-related additives were deemed unnecessary; the formulation was redesigned by reducing dispersants and friction modifiers to maximize protective film formation on sliding surfaces. In addition, instead of using viscosity-index improvers (commonly adopted in conventional low-viscosity ATF designs), the study employed an alternative anti-seizure strategy based on rapid formation of adsorption and reaction films. Two phosphorus-based additives were combined: an adsorbing type effective at low contact pressure and low speed, and a chemically reactive type effective at high pressure and high speed. This combination improved responsiveness to steep load fluctuations and enhanced seizure resistance under high load.

Performance evaluations demonstrated superior gear seizure resistance in a high-speed gear test under conditions representing poor lubrication and BEV launch driving. In a three-shaft reduction unit, the developed oil reduced churning losses and improved unit efficiency by approximately 10% (Fig. 1). In a prototype compact e-axle, motor coil temperature decreased by 4℃ , confirming improved cooling performance (Fig. 2). Overall, the developed oil achieved benchmark-leading low viscosity while maintaining high electrical insulation and meeting or exceeding the required reduction-gear oil properties (e.g., wear resistance, pitting life, material compatibility, and defoaming). The authors also conclude that reduced oil film thickness may help mitigate the risk of electrical corrosion in bearings, contributing to broader electrified vehicle adoption and future lubricant design.

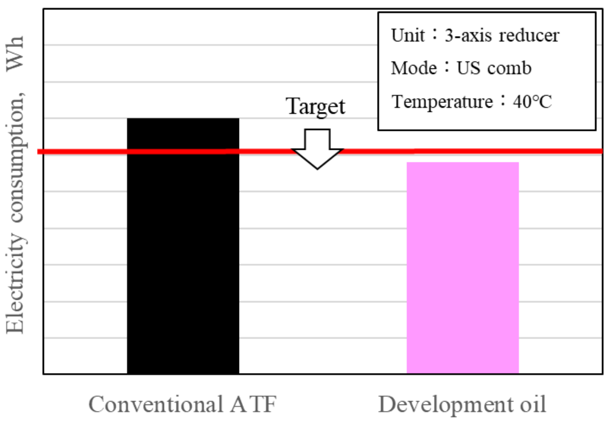

Fig. 1 Friction measurement results of the reduction unit

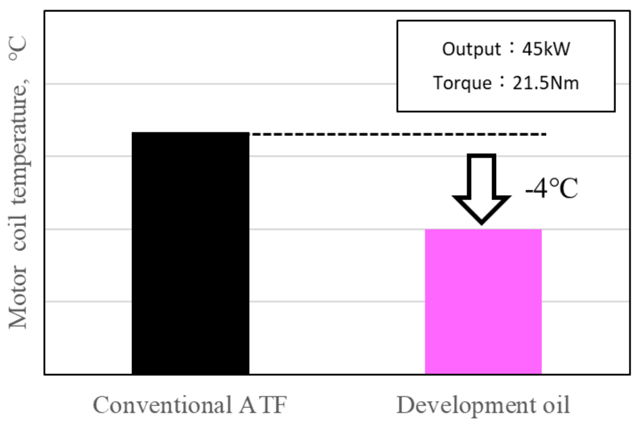

Fig. 2 Measurement results of motor coil temperature