

Anti-Seizure Polymer Additive for e-Fluids Used in E-Axle Drive Units

R & D Group of
Performance Polymer Division
(at the time of writing)
Chief

Ueno Kazushi

As vehicle electrification accelerates worldwide, the performance requirements imposed on lubricants for electric drive units have become increasingly complex. Along with this trend, highly efficient electric drive units known as eAxles—integrated systems combining a motor, inverter, and reduction gear—have been increasingly adopted. Lubricants used in eAxles, hereinafter referred to as e-fluids, are required to satisfy multiple performance requirements, including anti-seizure performance, cooling performance, electrical insulation, and copper corrosivity. These properties directly affect the energy efficiency* (distance per kWh) and reliability of electric vehicles. This article introduces ACLUBE NS-100, an anti-seizure polymer additive developed specifically for e-fluid applications.

* Energy efficiency (distance per kWh) refers to the distance an electric vehicle can travel per kilowatt-hour (kWh) of electrical energy. Improved electric efficiency enables longer driving distances with lower power consumption.

Electrification of Vehicles and the Role of eAxles

Efforts to mitigate global warming caused by greenhouse gas emissions such as CO₂ have been advancing worldwide. In the transportation sector, which accounts for approximately 22% of global CO₂ emissions, regulations on gasoline-powered vehicles have been tightened, while adoption of electrified vehicles—including BEVs (Battery Electric Vehicles), PHEVs (Plug-in Hybrid Electric Vehicles), and HEVs (Hybrid Electric Vehicles)—has accelerated due to their contribution to

CO₂ emission reduction¹⁾.

To further improve the electric efficiency of electrified vehicles, various technologies are being developed. Among these, the eAxle plays a particularly important role. By integrating components that were previously arranged separately—such as the motor, inverter, and reduction gear—into a single unit, eAxles enable weight reduction, space savings, and greater design flexibility. In addition, improvements in thermal management efficiency and reductions in electrical losses contribute significantly to enhanced electric efficiency (Figure 1).

Performance Requirements for e-Fluids

Lubricants used in the reduction gears of eAxles are referred to as e-fluids. Their primary role is to reduce friction, wear, and seizure at sliding components such as gears, thereby ensuring smooth mechanical operation.

In recent years, oil-cooled eAxle systems have been increasingly adopted, in which



Fig. 1 eAxle—an integrated unit combining the motor, inverter, and reduction gear required for vehicle drive

e-fluids also function as a cooling medium to suppress efficiency losses caused by motor temperature increases. In such systems, the e-fluid is supplied to motor components—including coils and rotors—by dripping, partial immersion, or spraying, enabling effective heat removal.

Lowering e-fluid viscosity is an effective approach for improving cooling performance. In addition, reduced viscosity lowers churning resistance at sliding components such as gears, contributing to improved electric efficiency.

At the same time, because e-fluids come into direct contact with electric motors, sufficient electrical insulation is required to prevent leakage currents and short circuits. However, excessively high insulation may lead to electrostatic charging, which can cause malfunctions or performance degradation. Therefore, electrical insulation must be appropriately balanced. Furthermore, high resistance to copper corrosion is essential to protect copper wires in motor coils that come into contact with the e-fluid.

Technical Challenges of e-Fluids

While lowering e-fluid viscosity is effective for improving cooling performance and reducing churning losses, excessive viscosity reduction results in thinner oil films. This increases the risk of seizure at sliding components and increases the risk of seizure-related failures in drive units. Accordingly, low-viscosity base oils must be combined with additives that provide sufficient anti-seizure performance.

However, conventional sulfur- and phosphorus-based additives, while effective in improving load-carrying capacity, exhibit high polarity and chemical reactivity. These characteristics can adversely affect electrical insulation and increase the risk of copper corrosion, limiting their applicability in e-fluids. In particular, sulfur-based additives are generally avoided in e-fluid formulations.

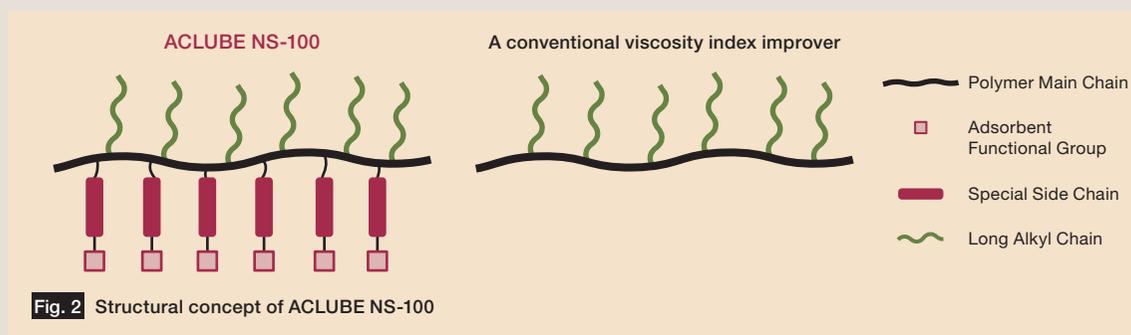
Conversely, reducing sulfur- and phosphorus-based additives to improve electrical insulation and copper corrosivity tends to increase the risk of seizure. Thus, achieving a balance between anti-seizure per-

formance and electrical insulation and copper corrosion resistance of e-fluids represents a key formulation challenge.

To address these challenges, ACLUBE NS-100 was developed as an anti-seizure polymer additive for e-fluids used in eAxle drive units.

Design Concept of ACLUBE NS-100: Anti-Seizure Polymer Additive for e-Fluids

ACLUBE NS-100 is based on organic polymer technologies cultivated through the ACLUBE products, which has been widely used as viscosity index improvers for engine oil and automotive lubricants. The polymer is designed using proprietary technology that combines monomers containing long-chain alkyl groups with monomers incorporating highly polar, adsorptive functional groups positioned at the termini of long side chains (Figure 2). These adsorptive functional groups selectively adsorb onto metal surfaces, forming a protective oil film even under low-viscosity conditions. At the same time, the polymer backbone is entirely



organic and does not contain sulfur or phosphorus, ensuring that electrical insulation and copper corrosivity are not adversely affected.

<Anti-Seizure Performance>

Anti-seizure performance under low-viscosity conditions was evaluated using a high-speed Shell four-ball test in accordance with ASTM D2783. In this test, the upper steel ball is rotated while the applied load is gradually increased, and the last non-seizure load is determined. A higher last non-seizure load indicates superior resistance to seizure and improved lubricity.

Figure 3 shows the last non-seizure loads for test oils prepared by adding ACLUBE NS-100 or ACLUBE A-1061—a conventional viscosity index improver for drivetrain lubricants that does not contain adsorptive functional groups—to a commercially available e-fluid.

The results indicate that the last non-seizure load of the oil containing ACLUBE NS-100 increased by approximately 25% compared with both the base e-fluid and the e-fluid containing ACLUBE A-1061. These results demonstrate that effective anti-seizure performance can be achieved through the introduction of adsorptive functional groups, without increasing additive polarity or relying on sulfur- or phosphorus-based additives. As a result, ACLUBE NS-100 reduces the risk of drive unit failure due to seizure, contributing to higher efficiency and longer service life of gear sliding components.

Further improvements in seizure resistance can also be achieved through combination with other additives, such as phosphorus-based compounds.

<Electrical Insulation>

Electrical insulation was evaluated by measuring volume resistivity ($\Omega \cdot \text{cm}$), which represents electrical resistance per unit volume. Measurements were conducted at room temperature for the same test oils used in the anti-seizure evaluation (Table 1).

The addition of ACLUBE NS-100 resulted in only an approximately 3% increase in volume resistivity, indicating that its impact on electrical insulation is negligible. Although

the adsorptive functional groups required for anti-seizure performance are highly polar, their introduction is minimized, and highly insulating long-chain alkyl groups are incorporated simultaneously. As a result, the polymer as a whole maintains an appropriate level of electrical insulation comparable to that of the base e-fluid.

< Copper Corrosivity >

Copper corrosivity was evaluated using a copper strip corrosion test in accordance with ASTM D130. In this test, a polished copper strip is immersed in the test oil and exposed to elevated temperature conditions, after which the

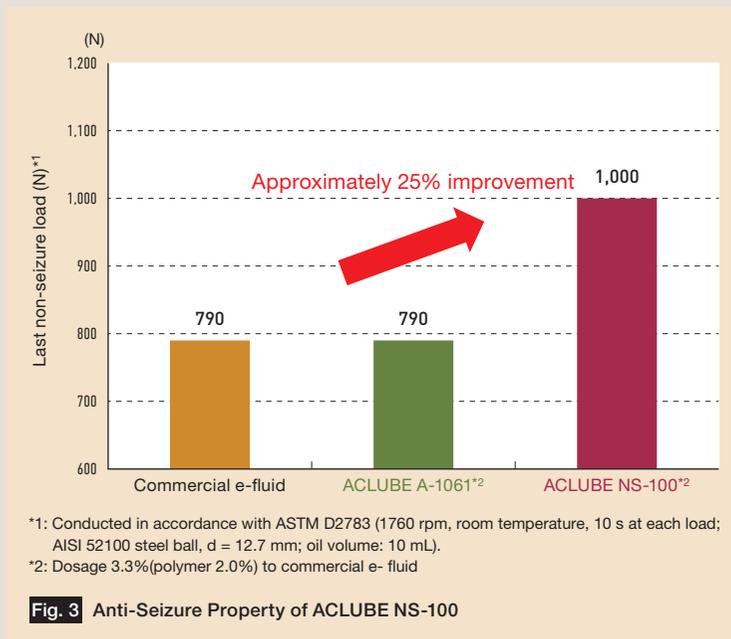


Fig. 3 Anti-Seizure Property of ACLUBE NS-100

Table 1 Electrical Insulation of ACLUBE NS-100

	ACLUBE NS-100	ACLUBE A-1061	Commercial e-fluid
Volumetric resistivity ($\Omega \cdot \text{cm}$) ^{*1}	1.96×10^{10}	1.87×10^{10}	1.90×10^{10}

*1 Measured using a non-aqueous conductivity meter (DT-700) at room temperature.

appearance of the copper strip is examined.

In all test oils, including those containing ACLUBE NS-100, the copper strips retained a brass-like appearance, with no evidence of corrosion (Table 2). These results confirm that the addition of ACLUBE NS-100 provides copper corrosivity equal to that of conventional products, without causing any deterioration.

In addition, oxidation stability—another essential requirement for e-fluids—was evaluated, confirming that viscosity increase and oxidative degradation remain minimal even after extended testing.

Conclusion and Future Outlook

ACLUBE NS-100 has demonstrated high anti-seizure performance, as well as excellent electrical insulation and copper corrosivity, making it well suited for low-viscosity e-fluid

formulations used in eAxle drive units. Field evaluations conducted by lubricant manufacturers in Japan and overseas have confirmed its reliability, and adoption by multiple customers, including major end users, is already progressing.

Beyond applications in electric vehicle drive units, ACLUBE NS-100 is expected to be applicable to a wide range of industrial machinery and mobility systems where higher efficiency is required. In particular, in cooling-integrated lubrication systems that increasingly employ low-viscosity oils, the risk of seizure tends to increase. Under such conditions, additives such as ACLUBE NS-100, which provide a well-balanced combination of multiple performance attributes, are expected to play an important role in future technological innovation.

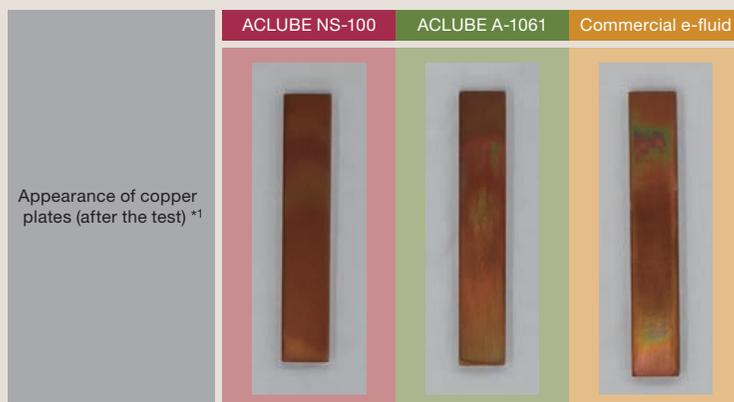
Sanyo Chemical will continue to respond to the diverse

needs of users by pursuing higher performance and technological innovation, while also expanding the application of this technology to various electrified mobility and industrial machinery fields. Through these efforts, the company aims to contribute to the realization of a more sustainable society.

References

- 1) IEA, Global CO₂ emissions from transport by sub-sector in the Net Zero Scenario, 2000–2030

Table 2 Copper Corrosivity of ACLUBE NS-100



*1: ASTM D130 Cu-strip test at 150°C/48hr.

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