

Development of Technologies for Miniaturization, High Efficiency, and High Torque Density in an e-Axle

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The rapid expansion of vehicle electrification has increased the demand for compact and highly efficient electric drive systems, particularly in A-segment vehicles and part-time 4WD applications where installation space is severely restricted. To address these requirements, a compact e-Axle was developed with a focus on achieving miniaturization, high efficiency, and high torque density while maintaining the performance required for practical vehicle applications.

The developed e-Axle integrates the motor, gearbox, and inverter into a highly optimized package. By adopting a parallel two-axis gear layout and efficiently utilizing internal space, the overall unit dimensions were reduced to 402 mm × 349 mm × 236 mm with a total mass of 48 kg. As a result, the new unit achieves approximately 60% volume reduction and 30% weight reduction compared with a conventional model. The compact package enables installation within the tire inner diameter, contributing to improved vehicle packaging through increased cabin space, lower cargo floor height, and a lower center of gravity.

To realize miniaturization, a high-speed motor with a maximum speed of 17,500 min⁻¹ was developed. Increasing motor rotational speed reduces the torque required from the motor itself, allowing the rotor diameter and stator size to be reduced while maintaining the required differential shaft torque through a high gear ratio of 12.08. Furthermore, a dual V-shaped magnet arrangement was adopted to improve rotor mechanical strength under high centrifugal forces, enabling reliable high-speed operation. An oil-cooling system shared with the gearbox was also implemented, eliminating the need for oil seals and reducing axial length while improving system integration.

High efficiency was achieved through comprehensive loss reduction technologies applied to the motor, inverter, and gearbox. The motor utilizes bonded laminated steel sheets to reduce eddy-current losses associated with conventional mechanical fastening methods. Magnet losses were further reduced through an optimized magnet segmentation structure. In the inverter, RC-IGBT devices, high-speed switching control, and adaptive gate resistance control were employed to minimize switching losses, particularly under light-load operating conditions. In addition, a forced lubrication system and low-viscosity oil were adopted in the gearbox to reduce oil churning losses while maintaining sufficient lubrication performance.

High torque density was realized through improvements in both electromagnetic performance and structural design. The winding space factor was increased by 3.9%, resulting in higher torque generation capability. Additionally, optimization of the magnetic circuit, including the flux barrier geometry, enabled rotor-core weight reduction while maintaining torque output. Structural optimization of each component reduced overall mass while maintaining durability and strength requirements, leading to approximately 30% weight reduction compared with the previous model. Consequently, torque per unit mass was significantly improved.

The results demonstrate that the developed e-Axle successfully combines substantial reductions in size and weight with high efficiency and high torque density. The technologies presented in this paper provide an effective solution for future electrified A-segment vehicles and part-time 4WD vehicles, enabling both superior vehicle packaging and the dynamic performance demanded by next-generation electric mobility.

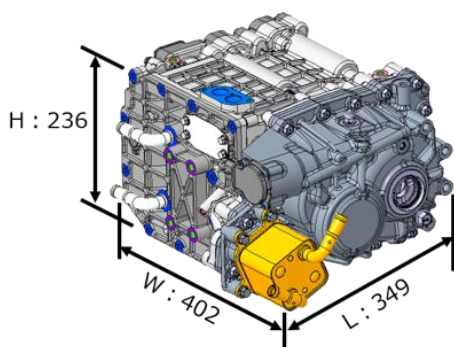


Fig.1 e-Axle Configuration

Table.1 Main Specifications

Max. Power (kW)		60
Cont. Power (kW)		30
Motor shaft	Max. Torque (N·m)	150
	Cont. Torque (N·m)	60
	Max. Speed (min ⁻¹)	17,500
Gear ratio		12.08
Diff shaft	Max. Torque (N·m)	1,750

※DC voltage of 280 V