ニュースリリース News Release

Toyo Denki Announces Successful Test of Electric Vehicle Equipped with World's First Wireless-Power-Transfer In-Wheel Motor

Tokyo, May 20, 2015 — Toyo Denki Seizo K.K. (hereinafter Toyo Denki) announced today that it has conducted a successful test of an experimental electric vehicle (EV) equipped with a wireless in-wheel motor (W-IWM) employing wireless power transfer. The W-IWM, the first of its kind in the world, was jointly developed by a research group led by Associate Professor Hiroshi Fujimoto of the Graduate School of Frontier Sciences at The University of Tokyo, NSK Ltd, and Toyo Denki.

Toyo Denki is committed to the advancement of next-generation EVs through the ongoing development of vehicle electrical products that employ new motor drive technologies.

1. Details of the Invention

Conventional in-wheel motors (IWMs)[1] for EVs are powered by connecting electrical wires to the vehicle power source in order to drive the wheels. The joint research sought to develop a wireless in-wheel motor (W-IWM) in which both power and control signals are transmitted wirelessly (Figure 1). This led to the world's first successful test of an experimental EV equipped with the W-IWM (Figure 2).

The W-IWM, the first of its kind in the world, uses magnetic resonance coupling[2] to achieve wireless power transfer between two coils separated by a gap of 10 centimeters. This configuration fully eliminates electrical wires between the vehicle chassis and the wheels.

Figure 1　Wireless In-Wheel Motor (W-IWM)

Figure 2　Experimental Vehicle with W-IWM

2. W-IWM System

Due to the motion of suspension links, the relative position of the IWM and the vehicle chassis changes, requiring the use of a magnetic resonance coupling that is not affected by changes in the power coil alignment. Figure 3 shows a simplified configuration diagram of the W-IWM.

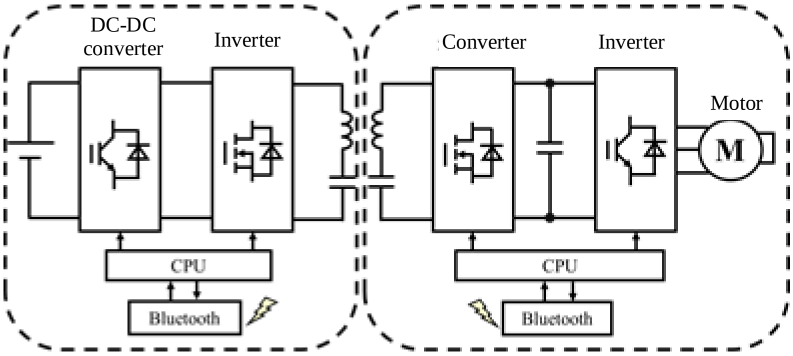

Figure 3　Configuration Diagram of W-IWM

There are a few possible circuit configurations for magnetic resonance coupling, depending on how the resonance capacitor[3] is inserted. The W-IWM does not require circuit switching during power regeneration, enabling the resonance capacitor and coil to be in series on both the primary and secondary side. The primary power conversion circuit uses a DC-DC converter[4] and inverter.[5] After the battery voltage is changed to a suitable voltage, the supply voltage is converted by the inverter to a high-frequency voltage, with the same frequency as the resonance frequency of the coil and resonance capacitor. The converted power is wirelessly transferred by magnetic resonance coupling. The received power is converted to DC by the converter[6] in the secondary circuit, driving a permanent magnet synchronous motor[7] using a motor drive inverter. The system can regenerate electric power without any problems.

3. Research Background (IWM Potential)

EVs offer various advantages due to their superior driving performance. Conventional IWMs are housed in the vehicle wheel and supplied with power through wires connected to the vehicle chassis, which involves a complex connecting configuration of power cables and control wiring. There is also the risk of an interruption in the wiring due to bending from vibration, freezing in cold environments, and impact from debris. Vehicle motors are warranted to last more than 10 years, and the risk of wiring interruption has been a barrier to the adoption pf IWMs in vehicles.

To overcome these shortcomings by completely eliminating wires, the research group sought to develop a W-IWM that uses wireless power transfer employing magnetic resonance coupling, and power conversion employing SiC devices.[8] The successful W-IWM that was developed removes the risk of wiring interruption, significantly improving safety and reliability.

4. Social Relevance

EVs deliver outstanding environmental performance, while also achieving superior driving performance due to their quick motor response. By housing the drive source in the wheels, IWMs enable power to be directly transferred to the wheel, which is ideal as a drive system. EVs equipped with an IWM directly transfer the drive power to all four wheels independently using drive power control, effectively eliminating the mechanical loss that comes with using a drive shaft, while also reducing the vehicle weight and enabling independent control of each wheel. This improves safety by preventing tire slippage, and realizes other advantages such as extending the maximum driving distance by enabling drive power to be optimally adjusted to each wheel.

However, conventional IWMs have to use cables to receive power from the vehicle chassis. The W-IWM eliminates the risk of wiring interruption between the IWM and inverter,[3] to improve safety and reliability. The development of the W-IWM promises to pave the way for the widespread adoption of IWMs.

5. Future Research

The W-IWM offers the potential for charging while on the move, which could extend maximum driving distance and eliminate the need for large-capacity batteries. The experimental EV that was developed has a lower output than EVs that are available to consumers today. Future research will concentrate on increasing the power output and realizing vehicle power supply on the move from ground sources.

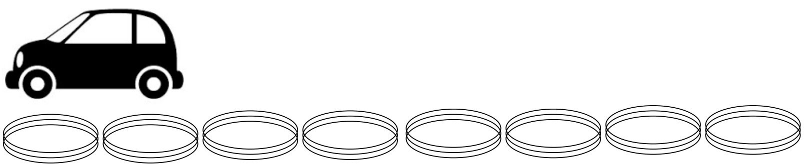

Figure 4 Concept for Power Supply on the Move (on Designated Highways)

6. Possibilities for W-IWM

The W-IWM addresses the risk of wiring interruption to improve reliability, and has the potential to deliver outstanding driving performance in EVs equipped with the motors. In principle, the W-IWM can also be used in fuel cell vehicles and hybrid vehicles. Looking further ahead, the development of infrastructure using ground coils opens the door to EVs that receive power externally without relying on batteries.

7. Terminology

1. **In-wheel motor:** A motor that is housed inside a wheel.
2. **Magnetic resonance coupling:** A wireless power transfer system that uses a resonance capacitor on the primary (power supply) side and secondary (power receiving) side to achieve resonant transfer. The system enables power transfer across a larger distance than is possible with magnetic induction, and offers superior transfer efficiency.
3. **Resonance capacitor:** A capacitor that is connected in series with the supplying coil and receiving coil, for magnetic resonance coupling.
4. DC-DC converter: A switching power supply that converts DC voltage to another DC voltage, using a regenerating circuit.
5. Inverter: A device that changes DC voltage to a three-phase AC voltage at a specific frequency and amplitude, supplying power to drive the motor.
6. Converter: A device that converts AC voltage to a specific DC voltage.
7. Permanent magnet synchronous motor: A synchronous motor that, in place of a winding, uses a permanent magnet (a magnet that retains its magnetic properties for an extended period, without receiving an external magnetic field or current).
8. SiC device: A device made from silicon carbide (SiC), which has roughly 10 times the dielectric breadown field strength of silicon and delivers high resistance and low loss for advanced power devices.

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