

Development of High Voltage Wire for New Structure Motor in Full Hybrid Vehicle

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ABSTRACT

Driving motors for hybrid vehicles and electric vehicles require magnet wires that can endure use at high voltages of 650 V or more. The magnet wire is a main motor component with the electromagnetic steel sheets and magnets. Conventional motors generally assure insulation by using the two parts of the magnet wire and insulate paper. But this increases the motor space factor and hinders weight reduction. A new magnet wire with high insulation performance was used by forming thermoplastic resin onto an enameled layer in order to reduce the number of insulating parts and enhance motor performance.

The magnet wire (High-Voltage Wire: HVW) composed of polyetheretherketone (PEEK) resin. HVW can withstand the forming load during motor manufacture, secures durability for the automobile motor operating environment (Automatic Transmission Fluid: ATF), high temperatures) and can maintain high-voltage characteristics.

The new-structure motor specification that uses this HVW enables a tightly wound circuit structure. Compared to a previous-structure motor with the same core structure, the new motor increases the maximum torque and maximum power by 2.6% and 8.9%, respectively, and reduces the volume and weight by 24% and 26%, respectively. This HVW has been applied to Honda's new-structure (Honda Advanced Winding: HAW) motor that achieves top-in-class power and compactness. (1)

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1. INTRODUCTION

Recently, the market penetration of electrically driven vehicles is proceeding at a rapid pace, and application is expanding from compact vehicles to heavy-duty vehicles. The driving systems used in these vehicles are subject to constant demands for high torque, high power and high efficiency in order to realize good power performance and fuel economy. On the other hand, system size and weight reduction is needed to realize a system with high general flexibility for expansion to multiple models.

Honda's Intelligent Multi-Mode Drive (i-MMD) system uses two motors for driving and electric power generation. The driving motor provides power performance and the generating motor uses the engine power to generate electricity. Further space saving and high insulation performance are required of each insulating part to meet demands for smaller size and higher voltages.

Figure 1 shows the magnet wire and insulation structure of the previous Honda motor and the HAW motor. i-MMD is a high-voltage system with voltages up to 700 V.

		Conventional motor	New structure motor
			
Insulation	In-phase	Magnet wire	HVW
	Inter-phase	Magnet wire + insulate paper	HVW
Space factor		-	12%UP
Motor width		-	9%DOWN

Figure 1. Comparison of motor structures

The conventional motor uses enameled wire and film thickness is 0.1 mm or less. The insulate paper is mainly used to secure inter-phase insulation. The inter-phase electric potential difference is larger than the in-phase electric potential difference, so the film of magnet wire is unable to secure insulation, and insulate paper is added. Increasing film thickness of the magnet wire is a method of achieving insulation performance without increasing the number of parts and enabled the HAW motor structure. In addition, this method realizes tightly wound

coil-forming without insulate paper, which also enables to reduce the size compared to the conventional distributed winding structure (Fig. 2).

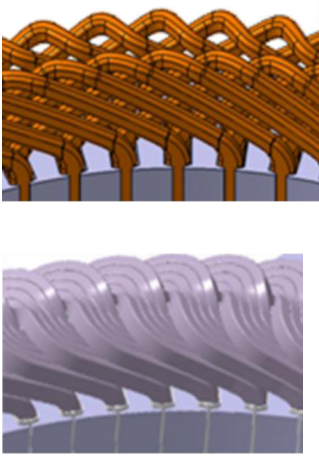


Figure 2. Coil end schematics

The motor application technology used HVW (made by Furukawa Electric Co., Ltd.) will be reported. Compared to the previous-structure motor, the developed HVW maintained the same efficiency, and helped to increase the maximum torque and maximum power by 2.6% and 8.9%, respectively, and reduce the volume and weight by 24% and 26%, respectively.

2. SPECIFICATION OF HVW

2.1. The Structure of Insulation Layer and Resin Materials

The conventional i-MMD motor uses a round wire that is suitable for configuring a distributed winding structure, but limits the space factor within the slot. Therefore, rectangular wire was used as the conductor to increase the space factor and reduce the motor size.

The insulation layer is composed of two-layer with enameled layer as the base and an extruded layer consisting of thermoplastic resin as the main (Fig. 3). Generally speaking, it is necessary to repeatedly coat the varnish to increase film thickness. However, the occurrence of pinholes is concerned. The addition of an extruded resin layer enables formation of a thick, pinhole-free coating with one process.

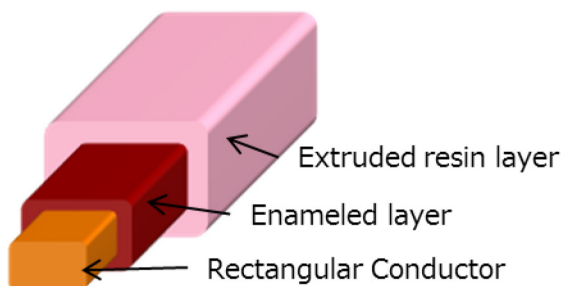


Figure 3. Structure of HVW

The coating material used in a motor located inside the transmission requires specifications enabling to withstand ATF and a high-temperature environment. Polyamideimide (PAI) was used as the base enamel layer. PAI has a thermal index of 220°C, and is a magnet wire coating material used mainly in automobile motors. PEEK resin was used as the thermoplastic resin of the extruded layer. PEEK resin has thermal index of 240°C. Figure 4 shows the positioning of insulating resins. Crystalline resin was decided in consideration of ATF durability.

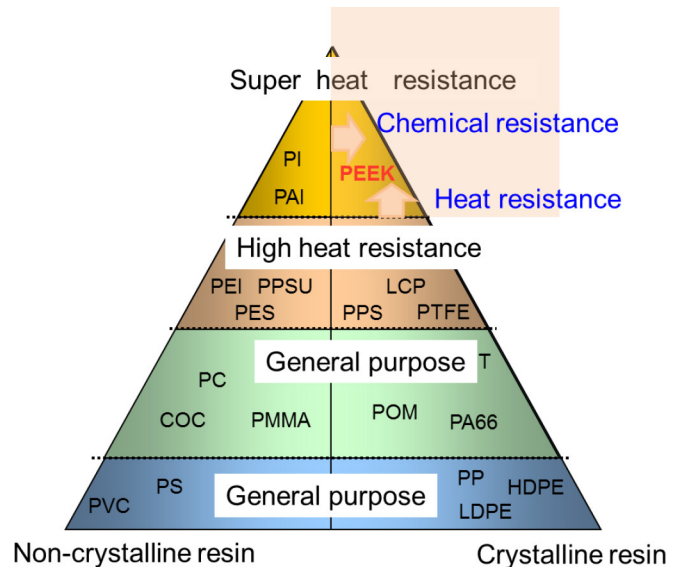


Figure 4. Positioning of resin materials

2.2. Film Thickness

Partial discharge occurs in voltage environments of 650 V or more, and leads to breakdown of the magnet wire insulation. Therefore, the film thickness needs to be set to a thickness at which partial discharge does not occur. Dakin's experiential formula(2) shown below is known to describe the relationship between the film thickness and the partial discharge inception voltage (PDIV). This coating has a two-layer structure, so the permittivity was synthesized from the equivalent circuit.

$$\text{PDIV} = 163 \times \left(\frac{t}{\varepsilon} \right)^{0.46} \quad (1)$$

ε : permittivity of insulation layer

t : thickness of insulation layer

$$\varepsilon = \frac{\varepsilon_1 \cdot \varepsilon_2 (t_1 + t_2)}{\varepsilon_1 \cdot t_2 + \varepsilon_2 \cdot t_1}$$

ε_1 : permittivity of PEEK resin

ε_2 : permittivity of PAI resin