Wiring harnesses for Next Generation Automobiles

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The weight of a wiring harness is increasing year by year because of newly added functions. In recent years, there are growing customer demands for environmentally friendly products, such as high-voltage wiring harness systems, for hybrid electric vehicles (HEVs) and electric vehicles (EVs) and weight-saving wiring harnesses systems designed to improve fuel efficiency. In order to satisfy these customer demands, we are developing a high-voltage wiring harness system and weight-saving electric wire and connection technology for a weight-saving wiring harness system. Although the gross weight of the wiring harness using a conventional electric wire is about 30 kg/car, weight savings of about 30% is possible by using a weight-saving electric wire.

1. Preface

Various new technologies for the environment, safety and comfort are applied to recent cars. In terms of wiring harness development, environmentally friendly products, such as hi-voltage wiring harness systems for HEVs and EVs and weight-saving wiring harnesses systems designed to improve fuel efficiency, are in strong demands. We are working on researching and developing to contribute to the environment through construction of a low-carbon society. This report describes the developments of high-voltage wiring harness systems for HEVs and EVs and lightweight wires, main components for the lightweight wiring harness systems.

2. Hi-voltage wiring harness system

2.1 Development result

We have developed products for ecological vehicles (eco-car, green-car), mainly for EVs since the early 1990s. Car manufacturers also have put new cars into market in rapid sequence since the late 1990s. High-voltage wiring harness systems differing from conventional 12 V systems are needed for developments of ecologically friendly cars. We have supplied our high-voltage wiring harnesses to 5 car manufacturers and over 10 system suppliers for more than 10 years as a result of our collaborative development efforts with them from the early development stages.

Field tests of the electric car prototype with our wiring harness started in 2005. After actual operations, Fuji Heavy Industries Ltd. decided to install Fujikura's high-voltage wiring harnesses into Plug-in Stella and put them on the market in 2009 (Fig.1).

1 Automotive Products R&D Department

Figure 2 shows the system outline of Plug-in Stella. Figure 3 shows the appearance of the high-voltage wiring harness for Plug-in Stella. We manufacture the

Fig. 1. Plug-in STELLA.

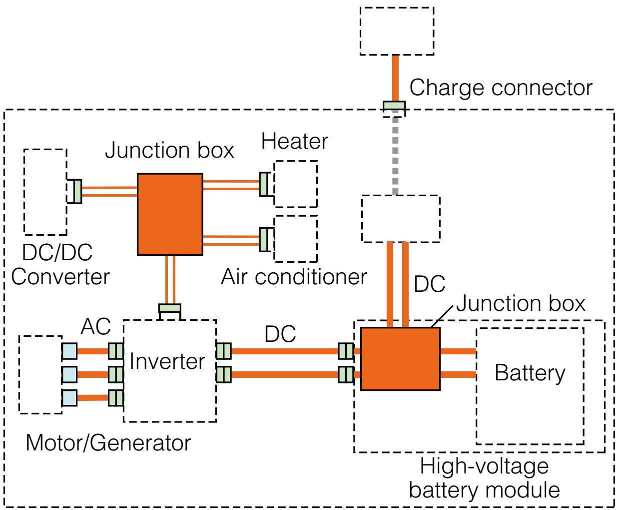

Fig. 2. System outline.

Abbreviations, Acronyms, and Terms.

HEV—Hybrid Electric Vehicle
EV—Electric Vehicle
WH—Wiring Harness
CA wire—Copper Clad Aluminum wire

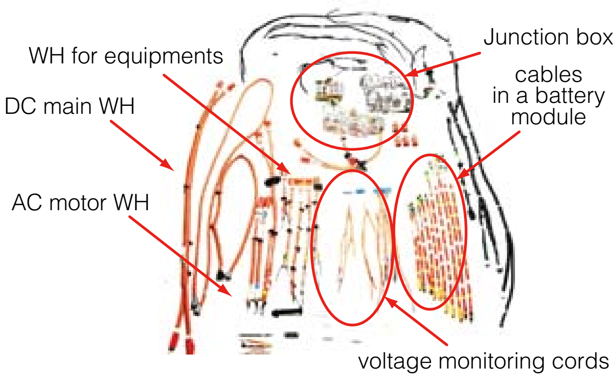

Fig. 3. High-voltage wiring harness.

Fig. 4. Electric Low and Full Flat Floor Bus.

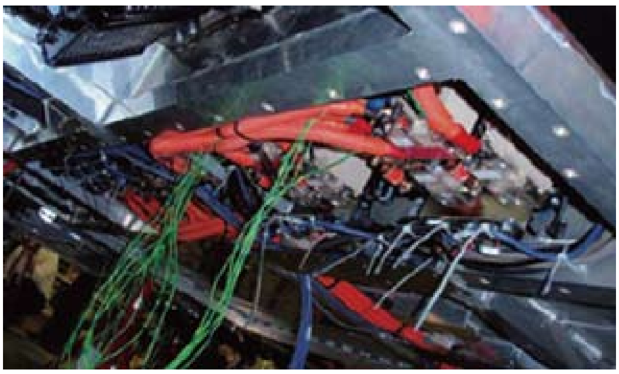

Fig. 5. High-voltage cable.

whole high-voltage wiring harness system of a car, including a junction box and the inner wiring system of the battery pack.

In 2010, Fujikura joined an industry-academia-government project of Keio Univ., Isuzu Motors Ltd., Kanagawa prefecture, and other companies, Research and Development of Electric Low and Full Flat Floor Bus (ELFB), and contribute to the development through supplying high-voltage cables. The bus has been under verification test in Kanagawa prefecture since 2011 with the aim of putting it to practical use (Fig.4, Fig.5).

2.2 Connectors for high-voltage wiring harness

To satisfy various customer requirements, our line-up of the connectors offers FHVC-Mark I, a connector for individual shielded wires and FHVC-Mark Ⅱ and FHVC-S, connectors with common braided shield that combines multiple non-shielded wires into one [1].

Furthermore, connectors for individual shielded wires are available in two types:

a pair of male and female connectors for connecting between wire harness and component/equipment (Fig.6), and bolt-on type connector that is directly bolted to the inside of electric equipments with its terminals (Fig.7).

Theses connectors feature a rating voltage of 600 V, seal ability of 98 kPa and shield performance higher than 40 dB. The contacts of the female connector itself has a rotating structure with a main conductor that allows multiple contacts for a large current as well a rotatable contact for braided shield. These features improved the workability of installing a thick cable to a car body.

Common shield connectors (FHVC-MarkⅡ and FHVC-S) reduced their parts number, achieved lightweight, cost reductions, and improved productivity by wrapping its multiple non-shielded wires. We have two types of connectors, a high-current connector for high-voltage main systems of 15 to 20 sq (mm^2) wires (Fig.8) and a low-current connector for electric equipment of 3 to 5 sq wires (Fig.9). Handling of braided shield wire is the key technical point. With contraption on the structure of the joint between braided wire and connector, this connector allowed productivity improvement as well as miniaturization.

Fig. 6. FHVC-Mark I (Connector type).

Fig. 7. FHVC-Mark I (Bolt-on type).

Fig. 8. FHVC-Mark II (Under Development).

Fig. 9. FHVC-S.

Table 1. Current wire and suitable light weight electric wire size.

Current wire size sq (mm^2)	Developed wire size sq (mm^2)	Suitable wire material	Benefits
0.13	0.08	High strength wire	High strength/ High conductivity
0.5 ~ 2	0.75 ~ 2.5	Aluminum wire	Low density/ High strength
3 or larger	5 ~ 100	CA wire	High conductivity/Low density

3. Lightweight electric wire

In the past, weight savings and thinning of automotive wires, from AV to AVS to AVSS to CAVUS (CHFUS, CIVUS), have been achieved through contraption mainly for thinning insulation material and devising conductor structures including circular compressed structure [2). But newer techniques are required as the former technology is approaching its limits.

We developed three types of new wires that will enable further reductions in weight and diameter according to their usage by reducing the specific gravity of conductors and strengthening them. One is an aluminum alloy automotive wire with high strength and high conductivity, another is copper-clad aluminum (CA) wire suitable for a thick wire such as a battery cable, and the last is a high strength wire suitable for signal lines that have the same strength with the one-quarter cross section to that of a current soft wire.

As each conductor material has a suitable application area, we can get a maximum effect of weight and wire size reductions by using them depending on the sizes as shown in Table 1.

Table 2. Characteristics of aluminum alloy wire.

	Tensile strength (Mpa)	Elongation (%)	Conductivity (%IACS)
marks	140 or higher	10 or higher	58 or higher
result	145.9	13	59.4

3.1 Automotive Aluminum alloy wires

An aluminum alloy wire is suitable for electric circuits smaller than 2.5 sq (mm^2) as low specific gravity materials. We set a goal of developing a conductor with equivalent or better electrical and mechanical characteristics compared with those of a copper wire. We also pay attention to terminal connecting strength required for an automotive wire along with electrical characteristics. Material characteristics required to attain the goal are Tensile strength 140 MPa or higher, Elongation 10 % or higher and Conductivity 58 % or higher. To achieve these objectives, based on various data of aluminum alloys, we selected the most effective strengthening method and succeeded in obtaining the material characteristics exceeding the marks finally (Table 2). It is known that aluminum alloy wires require different manufacturing processes from those of a conventional copper wire. We collaborated with the manufacturing department, and succeeded in its production.

As a result of these contraptions, the wires have world top-level balance of tensile strength, extensibility, and conductivity as automotive aluminum wires. Figure 10 shows the cross section of the aluminum alloy wire.

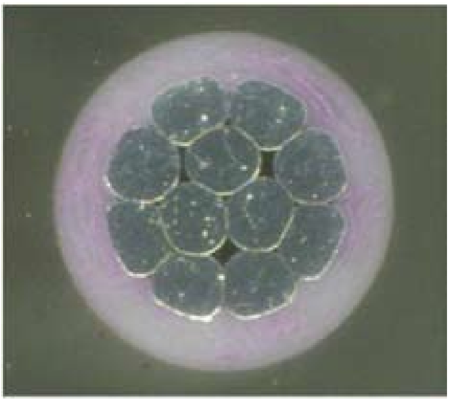

Fig. 10. Cross section of Aluminum alloy wire.

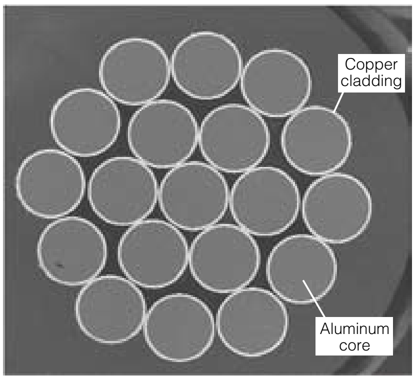

Fig. 11. Cross section of CA wire.

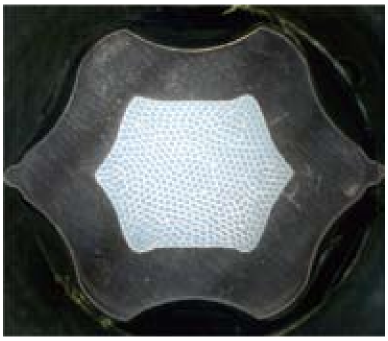

Fig. 12. Cross section of CA wire terminal.

3.2 Automotive copper-clad aluminum (CA) wires

Copper-clad aluminum (CA), a low gravity material, is suitable for a wire of a cross-section over 2.5 sq. As shown in Fig. 11, CA wires have a structure of an aluminum core conductor and copper cladding layer, and have both characteristics of copper's good conductivity and aluminum's high specific gravity-conductivity ratio. Also CA wires of 0.18 mm diameter that is normally difficult to process with a pure aluminum wire can be produced without any problem. Aluminum wire-terminal connections also have some difficulties in manufacturing. CA wires, however, have copper surface and thus enables electric connection by crimping using conventional terminals for copper wires, as shown in Figure 12, which means no additional investment needed. Using a CA wire in a thick cable results in a cable of light weight, thick but flexible, and high reliability.

We are the only one CA wire supplier in Japan. We have enough experience of manufacturing from the base material to the conductive wire and cord.

3.3 High-strength thin wire for automobiles

Several attempts have been made to use various materials except copper for thin electric wires designed specifically for signal lines. A 0.13 sq conductor of high-strength material and copper complex has been put into practical use along with copper alloy conductor.

One of the important objectives of the strengthening is keeping its crimped part strength in a certain value. Therefore, it is important to keep its crimped part strength higher than that of 0.3 sq copper wires. Considering wires smaller than 0.13 sq have been used for signal line for consumer use, there is still room for making thinner wires through conductivity improvement.

Among some approaches to accomplish a high strength conductor, we started our development with the aim of solving challenges by using combined materials. Although in study phase, we achieved 0.08 sq wires that have higher tensile strength of 0.3 sq conventional copper wires.

4. Conclusion

Copper conductor has been the mainstream material for automotive wiring harness. In the future, lightweight wires and harnesses of aluminum alloy or CA conductor will be the mainstream material to respond to demands for reducing weight for better fuel efficiency and to a run-up in copper prices. A total weight of copper conduct wire harness of a car is about 30 kg. About a 30 % weight reduction can be expected by using lightweight electric wires. As a wire harness system supplier, we will work on developing environment conscious wire harness systems such as high-voltage wire harness systems and lightweight wire harness systems.

References

1) K.Ishikawa, et al.: FHVC-MarkII, Fujikura Technical Journal No.119, p.53, 2010
2) M.Mochizuki, et al.: 0.13 mm^2, Fujikura Technical Journal No.119, p.52, 2010