New Shielding Construction of High-Voltage Wiring Harnesses for Toyota Prius - Winning of Toyota Superior Award for Cost Reduction -

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Along with the increase of electronic devices used in automobiles, the use of wiring harnesses for power and signal systems on board is growing remarkably. In these circumstances, the electromagnetic interference (EMI) generated by the power system should cause troubles on signal systems and other chassis-mounted electronic devices. Wiring harnesses act as the direct transmission lines of EMI, so the shielding has become an essential element of power wiring harness system. Generally, braided shield cables and shielded connectors have been used as the EMI shielding measures on the wiring harnesses. Such measures, however, resulted in the increase in cost and size of wiring harnesses. This paper describes the development of a low-cost shielded construction for high-voltage wiring harnesses applied in Toyota's hybrid electric vehicle (HEV), new Prius.

1. Construction of high-voltage harness

1-1 Conventional high-voltage harnesses using braided wire

Figure 1 shows the appearances of high-voltage wiring harnesses used to connect the motor and inverter of a Toyota Crown 42V (mild hybrid) and an Estima HEV, as well as the locations of these components on board.

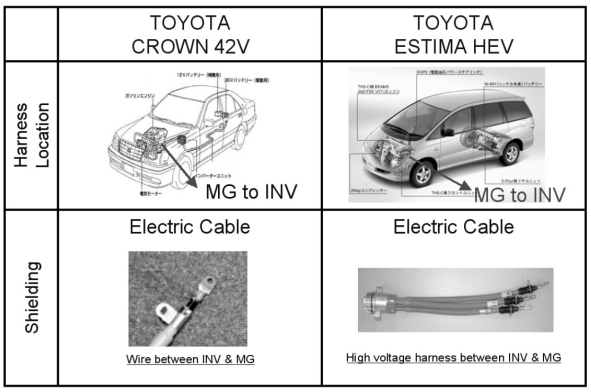

Fig. 1. High-voltage wiring harnesses: their appearances and locations in the vehicle

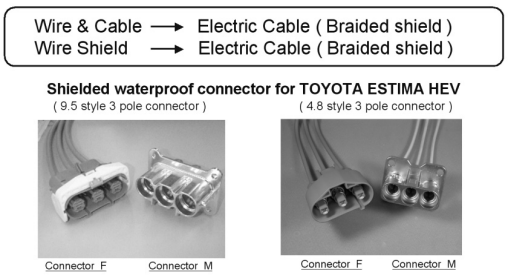

Fig. 2. Shielded high-voltage connector used in the Estima HEV

Both vehicles use braided shield cables together with shielded connectors, with the end of the braided shield connected electrically to the connector shield and high voltage unit.

The photographs in **Fig. 2** show shielded high-voltage connectors used in the Estima HEV.

Details of the construction for this connector for use with a shielded terminal construction connected electrically to the braided shield will be discussed later.

1-2 New high voltage wiring harness using a bundle shield construction

Figure 3 shows the high-voltage wiring harness used in the new Toyota Prius.

Figure 4 shows the component parts of this high-voltage wiring harness with bundle shield construction, both prior to and after assembly.

The wiring harness assembly comprises electrical wire and a waterproof connector, a bundle shield, and a sheath.

With the exception of the bundle shield, the other parts are basically the same as those used in a conventional waterproof wiring harness. In other words, the

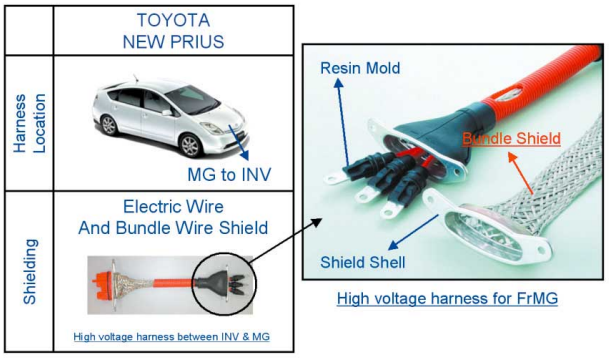

Fig. 3. Construction of high-voltage wiring harness for new Toyota Prius

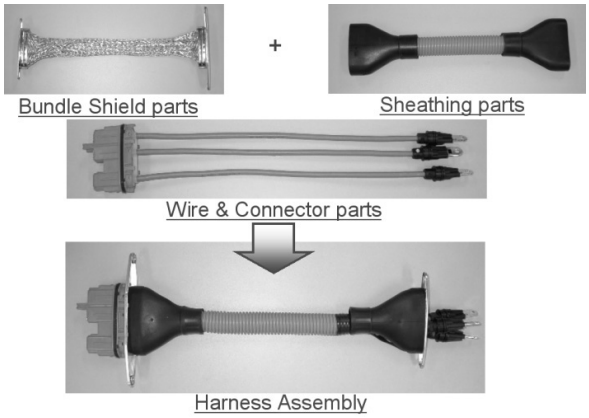

Fig. 4. Component parts of the high-voltage wiring harness

bundle shield is simply used to add a shield to a conventional wiring harness.

2. Construction of high-voltage connector

2-1 A comparison of high-voltage connectors

Figure 5 illustrates the differences between the construction of a shielded connector for individually shielded cables and one for a bundle shield construction.

As can be seen, the layout is very simple because the bundle shield are kept outside the waterproof connector construction.

Figure 6 illustrates the differences between connector attachments for the individually shielded cables and the bundle shield construction.

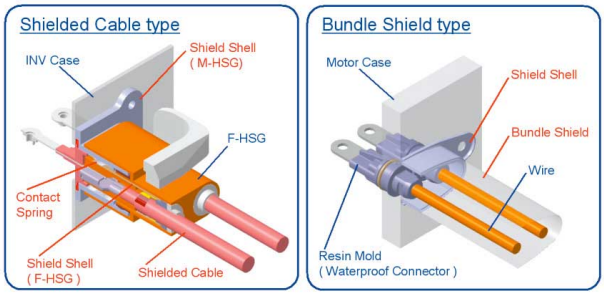

Fig. 5. A comparison of shielded connectors

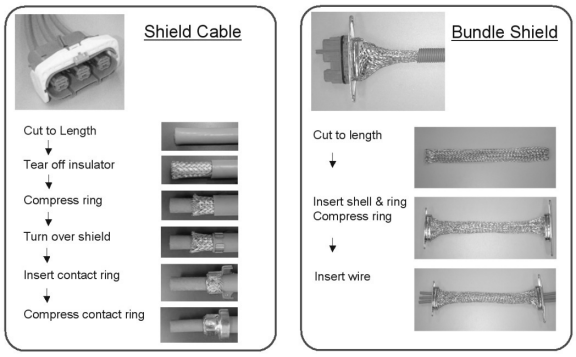

Fig. 6. Connector attachment

For individually shielded cables, there is a multi-step process involving removal of insulation, inversion of the shield, and attachment of a contact ring. For a typical three-pole motor circuit, this process must be performed for each of three cables.

In contrast, the bundle shield construction requires only that a ring be attached to the end of the shield, thus obviating the need to remove insulation or invert the mesh on individual cables. Although it does require the additional step of passing all three cables through the shield, there is no need to attach connectors to each wire individually because this construction bundles all three cables together.

2-2 A comparison of individually shielded cables and bundle shield construction

A comparison of the high-voltage wiring harnesses used to connect the motor and inverter in the Estima HEV with those used in the new Prius shows that the adoption of a bundle shield construction resulted in a reduction both in number of parts and number of steps in the assembly process, thereby achieving a major cost saving.

1) Change to a bundle wire shield system from a single wire shield
2) Cange the material of housing (aluminum → resin)
3) Reduce the number of molding processes for housing (2 times → 1 time)
4) Reduce the number of convoluted tubes (3 → 1)

Fig. 7. A comparison of the construction used for high-voltage wiring harnesses in HEVs

3. Performance of the bundle shield construction

The performance of the bundle shield construction was tested.

3-1 Measuring of shield performance

Shield performance was tested as shown in **Fig. 8** using an absorption clamp and in compliance with IEC 60096-1.

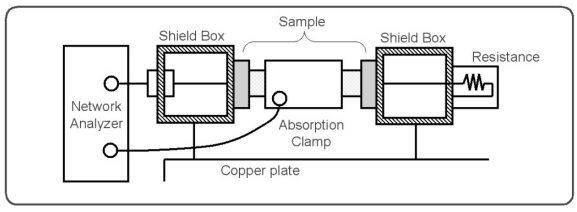

Fig. 8. Measuring of shield performance

3-2 Test Results

Figure 9 shows the test results for both individually shielded cables and bundle shield construction. A test frequency range of 0.1 to 100 MHz was used to match

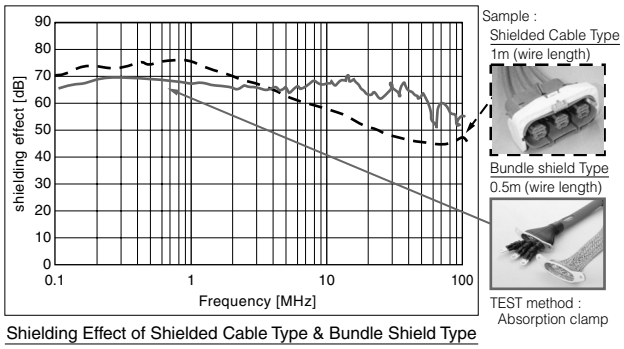

Fig. 9. Test results for initial shield performance

the range of EMI most likely to affect radio reception in automobiles.

Test results show that the bundle shield construction, including harness terminal connectors, was less effective than individually shielded cables by as much as 8 dB in the range below 4 MHz, but that above 4 MHz, it was more effective by as much as 20 dB.

It is known that this discrepancy stems not from inferior performance of the bundle shield construction but rather due to differences in construction of the wiring harness terminal shield connection. Thus, the authors see that there are no major differences in shield performance between individually shielded cables and the bundle shield construction.

Obviously, either type of shield affords sufficient protection against interference with automotive radio reception.

3-3 Shield performance after exposure to the environment inside the automotive chassis

One major difference between conventional individually shielded cables and the bundle cable construction is that, whereas the mesh of conventional individually shielded cables is covered with insulation, the shield of the bundle shield construction is exposed to the air.

Hence, the authors also tested performance of the shields after performing a salt exposure test per ISO 8092-2.

Figure 10 shows test results for shield performance both before and after the salt exposure test.

Shield performance is approximately 10 dB worse in the range up to 10 MHz. The probable cause is increased electrical resistance of the shield due to corroding of the braided wire.

There was, however, no discernable loss of performance overall, and even after the test, the shield afforded sufficient protection against interference with automotive radio reception.

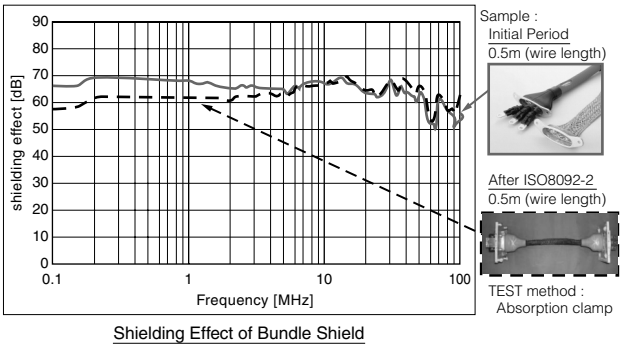

Fig. 10. Shield performance after durability testing

4. Conclusion

A bundle shield construction for high-voltage wiring harness used in HEVs was developed. The authors believe that this construction provides reliable shield performance at a reasonable cost.

Although shield performance does exhibit a certain amount of degradation after exposure to the air, it has demonstrated sufficient durability for practical use as a high-voltage wiring harness in HEVs.

The authors are confident that the bundle shield construction is a low-cost solution to protecting against interference with automotive radio reception.

References

(1) IEEE Committee on the 42 V Technologies "The Automotive 42 V Power Net Technologies", Ohmsha, Japan (2003)

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