Highly Heat-Resistant Flexible Flat Cable for Automotive Applications

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The flexible flat cable has been used for electric wiring of electronic appliances. Along with the increase of electronic equipment installation in automobiles, the application of flexible flat cables has been increasing. Sumitomo Electric Industries, Ltd. has successfully produced a new flexible flat cable for automotive use featuring high heat resistance up to 150°C.

Keywords: flexible flat cable, 150°C heat-resistant

1. Introduction

Flexible flat cables have been used for the internal wiring in various types of electronic equipment due to their particular characteristics (i.e., thin, lightweight, high-density wiring). We have been developing flexible flat cables for the automotive field. Specifically, we have commercialized 105°C and 125°C heat-resistant flexible flat cables as internal wiring materials for in-vehicle electronic equipment such as car navigation systems, LCD panels, and cameras, in addition to flat harnesses for doors and roofs.[1]

Recently, in-vehicle electronic equipment such as radars, cameras, and sensors has become increasingly common due to the increase in both sensing devices for automated driving and drivetrain devices for electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs). The consumption of cables for power supply and signal transmission for such electronic equipment is expected to increase. This paper provides the details of our newly developed 150°C heat-resistant flexible flat cable that can be used in even more severe environments than before.

2. In-Vehicle Flexible Flat Cable

2-1 Flexible flat cable

A flexible flat cable consists of flat rectangular conductors arranged in parallel that are sandwiched by two resin films (one each at the top and bottom) and laminated via an adhesive (see Fig. 1). The thickness of a flexible flat cable is between 100 and 300 µm. A polyethylene terephthalate (PET) film is often used as the resin film because of its excellent balance between mechanical characteristics, electrical characteristics, and price. However, an optimal film can be selected depending on the use environment and required characteristics.

In general, a polyester-based adhesive is used. We have developed proprietary adhesives with appropriate characteristics for the respective applications.

When a flexible flat cable is connected to a substrate via a connector, a supporting tape is attached to the end of the cable to ensure easy handling and to maintain its strength. We have also developed adhesives for such applications.

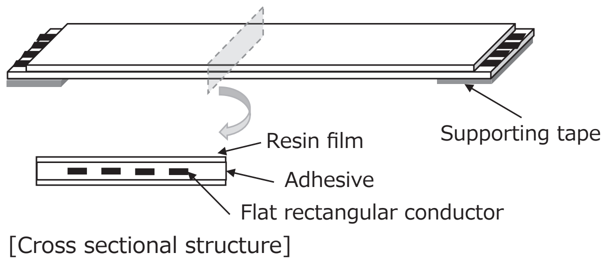

Fig. 1. Structure of a flexible flat cable

2-2 Target

We have commercialized 105°C and 125°C heat-resistant in-vehicle flexible flat cables. Typical applications are summarized in Fig. 2. The 105°C heat-resistant type is used as wiring materials for electronic equipment in the cabin such as car audio systems, car navigation systems, and LCD instrument clusters. The 125°C heat-resistant type is used for equipment that is exposed to higher temperatures (such as cameras and head-up displays).

Recently, there has been growing demand for flexible flat cables that can be used as internal wiring materials for electronic equipment exposed to higher temperatures such as inverters/converters, radars, and sensors due to the

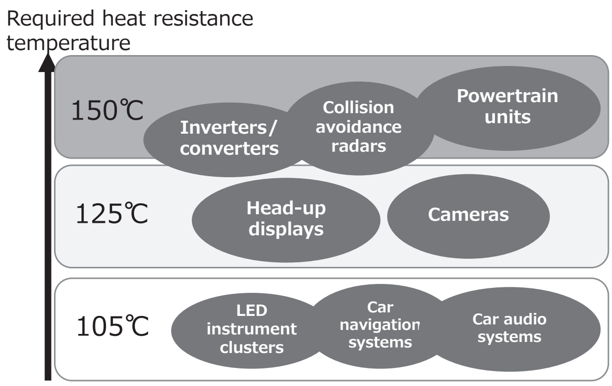

Fig. 2. In-vehicle equipment and required heat resistance temperature

recent increase in HEVs/PHEVs and vehicles equipped with components related to advanced driver-assistance systems (ADAS).

Against this backdrop, we worked on the development of a flexible flat cable that can be used in the 150°C environment.

3. Development

3-1 Development target

In developing a 150°C heat-resistant flexible flat cable, we referenced the JASO D611*1 and ISO 6722*2 standards for in-vehicle insulated wires and the SAE/USCAR-2*3 standard for automotive connectors. To offer a product that can meet the diverse requirements of customers, we established the development targets as shown in Table 1 to ensure conformity with the UL standard*4 by adding our original items and by taking into account potential deployment for electronic equipment other than in-vehicle applications.

Table 1. Main development targets

Item	Test condition	Target
Heat resistance	3000 h at 150°C	Insulation resistance in water 1,000 MΩ･m or more. Dielectric strength test at 1 kV for 1 min in water. No electrical breakdown.
Moist heat resistance	1000 h at 85°C85%RH	
Cold resistance	1000 h at -40°C	
Hot water resistance	840 h in hot water at 85°C	
Thermalshock resistance	1000 cycles between -40°C and 150°C	
Flame retardance	Vertical flame test (VW-1)	Passed (flame extiguished within 60 sec)
Delamination	168 h at 158°C	No delaminaton allowed

3-2 Development of an insulator adhesive

In general, polyester-based insulation adhesives are used for flexible flat cables. They can be used in a moist heat environment of 60°C 95%RH. However, hydrolysis of polyester molecules occurs due to the reaction shown in Fig. 3 in the target environment (85°C 85%RH), resulting in lower mechanical strength.

Polyester is a copolymer of dibasic acid and polyhydric alcohol. Various compounds can be synthesized from acids and alcohols. Thus, adhesives can be created for intended objectives.(2)

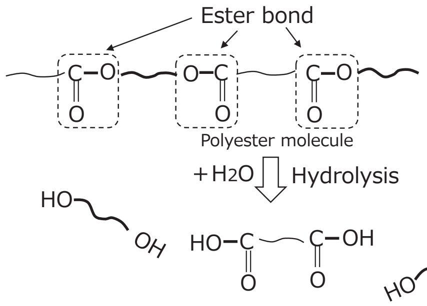

Fig. 3. Hydrolysis reaction of polyester

We have developed a proprietary adhesive that achieves heat resistance, moist heat resistance, and adhesive strength in a well-balanced manner by using a special polyester (whose heat resistance is 150°C and that is resistant to hydrolysis at 85°C 85%RH) as the main component in combination with adhesion promoter components characterized by excellent adhesive strength for the conductor.

Photo 1 shows a transmission electron microscopy image of the structure of this adhesive. The special polyester is dotted with islands of adhesion promoter components.

The special polyester (i.e., matrix) is considered to maintain the shape, while micro-dispersed adhesion promoter components are considered to ensure stable adhesive strength.

The changes in the adhesive strength for the conductor in a high temperature environment and moist heat environment are shown in Fig. 4.

The initial adhesive strength is maintained even after 3,000 hours at 150°C. This indicates excellent heat resistance. No reduction in adhesive strength is observed even after 1,000 hours at 85°C 85%RH. This indicates that the adhesive also has excellent moist heat resistance.

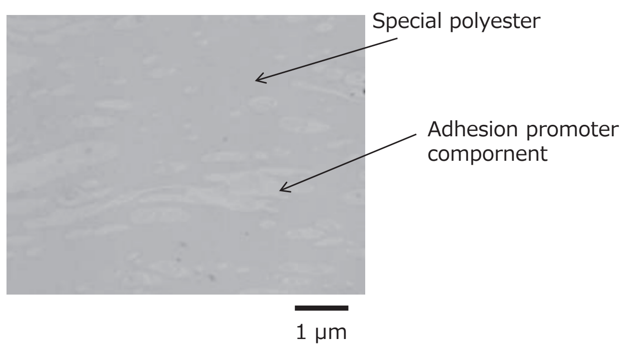

Photo 1. Transmission electron microscopy image of the newly developed adhesive

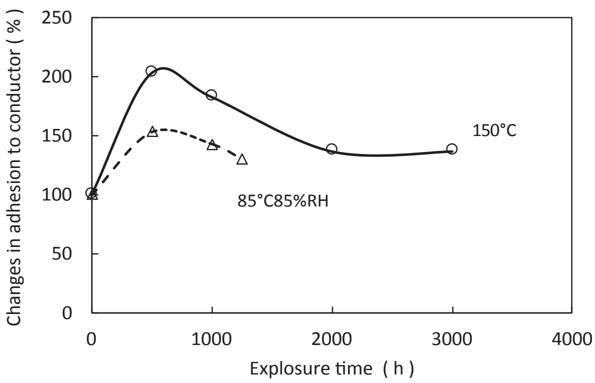

Fig. 4. Exposure time in the high temperature and moist heat environment and changes in adhesion to the conductor

3-3 Development of a reinforcement plate adhesive

A connector is often used to connect a flexible flat cable with a substrate. To increase the strength at the connector fitting part, it is necessary to attach a resin plate (supporting tape) to the end of a flat cable.

A supporting tape is attached to a flat cable via a hot-melt adhesive. When the conventional supporting tape adhesive is kept at 150°C while being fitted to a connector, the adhesive becomes soft and the contact pressure with the connector terminal decreases, resulting in an unstable connection.

As in the case of the insulation adhesive discussed above, we developed a heat-resistant supporting tape adhesive using polyester as the main material.

Figure 5 shows the deformation rate residue of the adhesive against the temperature change. The thermal deformation of the newly developed product is low even at 150°C.

We worked with a connector manufacturer to optimize the terminal design that meets the temperature characteristics of the adhesive.

As shown in Fig. 6, we achieved a highly reliable connection status with stable contact pressure without deformation of the reinforcement plate adhesive.

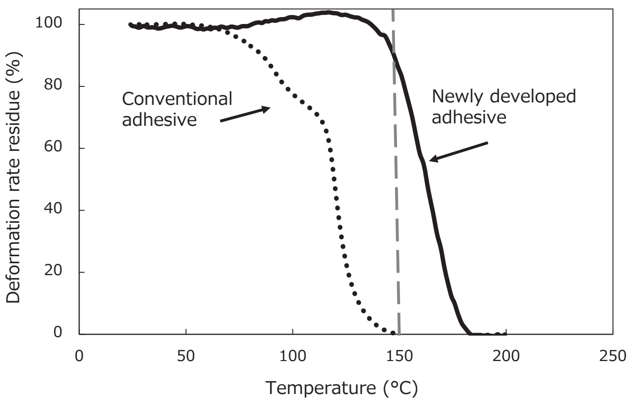

Fig. 5. Heat deformation of supporting tape adhesive

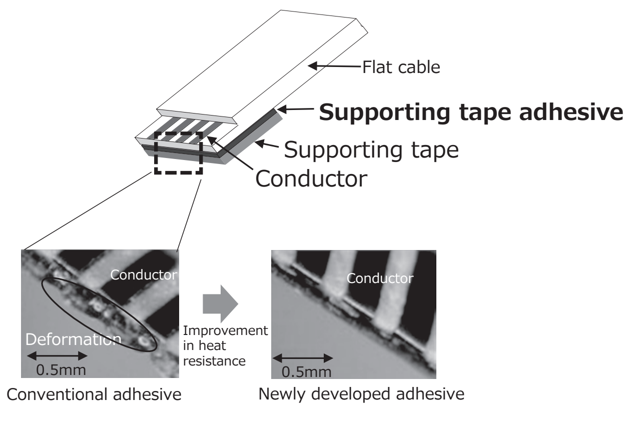

Fig. 6. After a connector fitting test (150°C)

4. Characteristics of the New Cable

We fabricated an insulation film by laminating the flame retardant adhesive (with a flame retardant added to the insulation adhesive, as discussed above) on a heat-resistant resin film.

We sandwiched flat rectangular conductors (0.035 mm thick, 0.3 mm wide) with insulation films and thermally laminated them to fabricate a flexible flat cable. We evaluated the characteristics of the flexible flat cable.

Table 2. Characteristics of a 150°C heat-resistant flexible flat cable

Item	Test condition	Target	Newly developed product
Heat resistance	3000 h at 150°C	Insulation resistance in water 1,000 MΩ･m or more Dielectric strength test at 1 kV for 1 min in water. No electrical breakdown.	Passed
Moist heat resistance	1000 h at 85°C85%RH		
Cold resistance	1000 h at -40°C		
Hot water resistance	840 h in hot water at 85°C		
Thermalshock resistance	1000 cycles between -40°C and 150°C		
Flame retardance	Vertical flame test (VW-1)	Passed (flame extiguished within 60 sec)	Passed
Delamination	168 h at 158°C	No delaminaton allowed	No delamination

4-1 Evaluation of heat resistance

We conducted a short-term heat resistance evaluation (delamination after 168 hours at 158°C) and long-term heat resistance evaluation (insulation resistance and dielectric strength tests after 3,000 hours at 150°C). No delamination occurred. The flexible flat cable also passed the insulation resistance and dielectric strength tests.

4-2 Evaluation of moist heat resistance and hot water resistance

We evaluated moist heat resistance by exposing the flexible flat cable to an environment at 85°C 85%RH for 1,000 hours. We evaluated hot water resistance by immersing the flexible flat cable in hot water of 85°C for 840 hours. The flexible flat cable passed the insulation resistance and dielectric strength tests.

4-3 Cold resistance evaluation

We kept the flexible flat cable at −40°C for 1,000 hours and warmed it to room temperature. The flexible flat cable passed the insulation resistance and dielectric strength tests.

4-4 Thermal shock resistance

We subjected the flexible flat cable to 1,000 cycles of cooling at −40°C for 30 minutes and heating at 150°C for 30 minutes. The flexible flat cable passed the insulation resistance and dielectric strength tests.

4-5 Flame retardance

We conducted a vertical flame test (VW-1) in accordance with the UL standard (a rigorous evaluation method). The flexible flat cable passed the test.

4-6 Connector fitting test

We fitted the supporting tape (using the highly heat-resistant supporting tape adhesive discussed above) to the

150°C heat-resistant connector developed in collaboration with a connector manufacturer. We conducted an evaluation in accordance with SAE/USCAR-2 rev. 6. It passed the Class T4 (150°C) test.

5. Conclusion

We developed a 150°C heat-resistant insulation adhesive and supporting tape adhesive, and used them to develop a high heat-resistant in-vehicle flexible flat cable that meets the requirements of the JASO and ISO standards for automotive insulated wires (in terms of heat resistance, low temperature resistance, and hot water resistance) and those of the SAE/USCAR-2 standard for automotive connectors.

We have been working to meet the specifications not only for in-vehicle equipment manufacturers in Japan but also for customers in Europe and the U.S. through sales offices outside Japan.

Applications other than in-vehicle equipment have been expanding due to the successful fulfillment of the UL standard and acquisition of UL Style 5556 (125°C 90 V rating).

Technical Terms

∗1 JASO standard: The JASO standard is established by the Japanese Automotive Standards Organization.

∗2 ISO standard: The ISO standard is established by the International Organization for Standardization.

∗3 SAE/USCAR-2: SAE/USCAR-2 is the standard for in-vehicle connectors established by the Society of Automotive Engineers, Inc.

∗4 UL standard: The UL standard is established by Underwriters Laboratories Inc.

∗5 Delamination: Delamination refers to a phenomenon in which the adhesive surfaces between the base film and adhesive or between the adhesives peel.

References

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