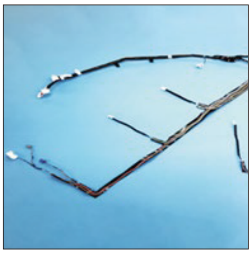


Structure and Key Technologies of e-STEALTH W/H

Hideki NOMURA*, Hosei MIZUNO, Kyousyou KOU, Takuya KABA, and Junichi SHIRAKAWA

The spread of autonomous driving and the movement toward CASE (connected, autonomous, shared & service, electric) vehicles has led to an increase in the number of devices and electrical circuits in automobiles. However, in order to improve comfort, there is a need to increase the interior space of vehicles, which requires a change in the wiring harness design to fit into smaller and tighter spaces. Meanwhile, the complex nature of wiring harness manufacturing makes it difficult to automate, resulting in a manual-intensive process that requires a large number of workers across global locations. This presents challenges in terms of cost and carbon emissions associated with long-distance shipping to OEM factories. To address these challenges, we have developed e-STEALTH W/H, a new wiring harness that not only increases interior space in vehicles but also enables automation, shifting from labor-intensive processes to localized production for local consumption. The successful adoption of our wiring harness by a major automaker underscores its effectiveness. This paper outlines the structure and key technologies of e-STEALTH W/H and provides insights into our innovative wiring harness solution.

Keywords: e-STEALTH W/H, local production for local consumption, automation, flat wiring harness

1. Introduction

Wiring harnesses*[1] have been increasing in size due to the shift to automated driving and higher functionalities of vehicles. The increase in the routing space poses concern about the reduction in the interior space. To increase the interior space, it is necessary to revolutionize the shape of the wiring harnesses because reduction in the diameter of the electric wires does not offer an adequate solution.

Meanwhile, it is considered difficult to automate the manufacturing process of wiring harnesses due to the complicated work involved. Thus, wiring harnesses are still manufactured by employing many people at respective sites around the world. From the viewpoint of cost competitiveness, long-distance transportation from manufacturing sites is unavoidable. For example, wiring harnesses for the North American market are manufactured at plants in Southeast Asian countries. This has made it difficult to avoid the problem of CO_2 emissions. Under these circumstances, the labor-intensive business model no longer works due to the COVID-19 pandemic and recent global semiconductor shortages. To address these challenges and achieve a breakthrough, we aim to build a local-production-for-local-consumption*[2] system as one of the measures.[(1)]

To increase the interior space and achieve local production for local consumption, we have developed a new flat wiring harness (hereinafter referred to as the "e-STEALTH W/H"). In the e-STEALTH W/H, the positions of the wires are controlled to achieve a flat arrangement. The height has been reduced by about 50% compared to that of a conventional wiring harness, and the automation rate has been significantly improved to enable easy manufacturing in regions where the manufacturing cost is high.

We succeeded in applying the e-STEALTH W/H to the roof harness and launched production in February 2022. Fig. 1 shows the application area in a vehicle and the appearance of the product.

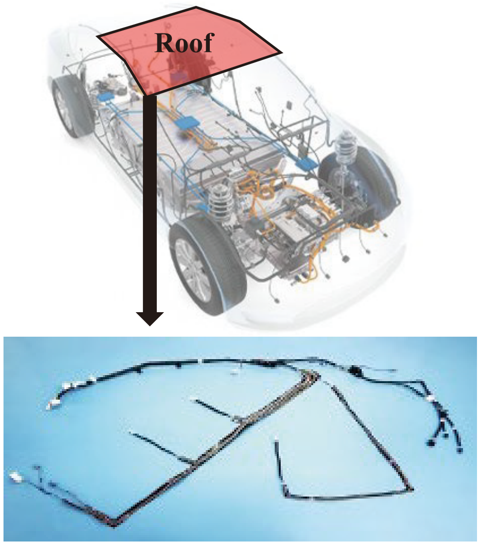


Fig. 1. Application area and appearance (photo) of the e-STEALTH W/H

2. Structure of the e-STEALTH W/H

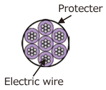
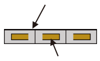
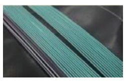
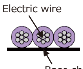
Flexible flat cables*[3] (FFCs) and flexible printed circuits*[4] (FPCs) are used as flat wiring harnesses installed in vehicles. However, their scope of application is limited due to failure to meet in-vehicle requirements, including connection reliability, compatibility with different types of wires, and adaptability to bending, branching, and cross-over routing. Thus, FFCs and FPCs are not widely used.

To meet in-vehicle requirements and ensure cost competitiveness against existing flat wiring harnesses, we invented a new flat structure to align and fix wires on the base sheet by using automotive wires and general-purpose connectors (Table 1).

In the conventional process of manufacturing wiring harnesses, the automation rate is about 15% of the entire process. The use of the new structure helps increase the automation rate to about 50%. The new structure is expected to realize local production for local consumption.

The technology to fix wires on the base sheet, which is the elemental technology for the e-STEALTH W/H, and the development of the base sheet are discussed below.

Table 1. Comparison between the e-STEALTH W/H structure and other wiring materials

		Auto-mation	Space	Cost	In-vehicle installation requirements Connection reliability Compatibility with different types of electric wires Bending, branching, and crossover routing
Conventional 	Cross section Protecter  Electric wire Electric wires are bundled.	Fair	Poor	Good	Excellent
FFC・FPC FFC 	Cross section Insulator  Conductor	Excellent	Excellent	Poor	Fair
e-STEALTH W/H 	Cross section **Flat structure** Electric wire  Base sheet **Electric wires are aligned and fixed on the base sheet.**	Excellent	Good	Good	Excellent

3. Technology to Fix Electric Wires on the Base Sheet

In general, adhesives and double-sided tape are used to fix wires to the base sheet. However, additional materials are required for the respective wires, and it is difficult to automate the manufacturing process. We focused on ultrasonic welding because it can be used with different types of wires based solely on direct welding of materials and control of conditions, and it is suitable for automation. Figure 2 shows the working principle of ultrasonic welding.

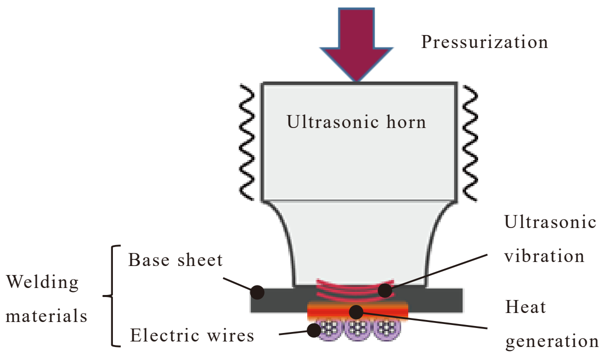


Fig. 2. Working principle of ultrasonic welding

In ultrasonic welding, welding materials are pressurized by an ultrasonic horn,*5 which generates ultrasonic waves. The ultrasonic vibration transmitted from the end surface of the ultrasonic horn to the welding materials propagates in the welding materials. Heat is generated between the welding materials, resulting in a softening and melting phenomenon*6 at the welding interface to enable fusion welding between the welding materials.

The ultrasonic vibration attenuates as the transmission distance increases. Thus, the closer the welding materials are to the ultrasonic horn, the more likely it is that heat will be generated. When ultrasonic vibration is applied from the wire side, the heat generated between the ultrasonic horn and the wires is greater than that between the base sheet and the wires, resulting in a higher temperature. This causes the deformation of wires on the ultrasonic horn side before welding the wires into the base sheet. By applying ultrasonic vibration from the base sheet side, heat is generated between the ultrasonic horn and the base sheet, enabling welding with the base sheet without deformation of the wires because the base sheet is not subject to the thermal effect due to the high melting point.

Ultrasonic welding is controlled by the pressing load and ultrasonic energy from the ultrasonic horn. When the pressing load or ultrasonic energy is too high, the quantity of heat generated at the interface increases. Thermal conduction to the entire sheath of wires results in softening and deformation of the wires. On the other hand, when the pressing load or ultrasonic energy is too low, the quantity of heat generated between the wires and the base sheet is small. The softening and melting phenomenon does not occur, and neither does welding. Accordingly, we established the ultrasonic energy and pressing load as the welding conditions, which can attain both the peel strength and deformation of the wires under the vehicle installation conditions and in the in-vehicle environment (Fig. 3).

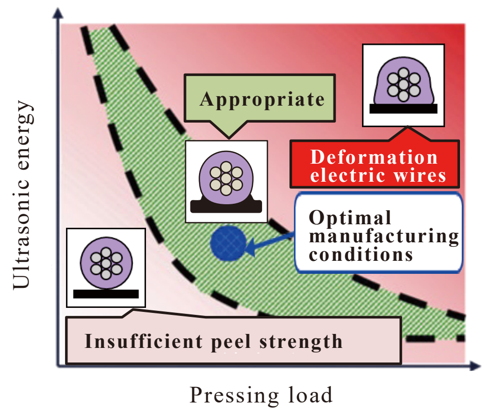


Fig. 3. Ultrasonic welding characteristics between the base sheet and the electric wire

We evaluated the ultrasonic welding characteristics and succeeded in ensuring a range of welding conditions depending on the type and number of wires.

4. Development of the Base Sheet

In the development of the base sheet, we aimed to impart the protecting functions and keep the route shape in addition to ensuring the welding characteristics with wires.

The details are described below.

4-1 Welding characteristics of electric wires and the base sheet

We established the following requirements in the development of the base sheet: to prevent the deformation of wires during welding with the wires, to attain the peel strength that prevents wires from coming off under the vehicle installation conditions and in the in-vehicle environment of wiring harnesses, and to ensure a wide range of welding conditions to achieve stable quality and manufacturing.

Electric wires become deformed if the base sheet is harder than the wires at the welding temperature. To prevent the deformation of the wires, the base sheet must be softer than the wires. Figure 4 shows the hardness of the wire sheath (namely, the “storage modulus”*7) against temperature and the target storage modulus at the welding temperature required of the base sheet.

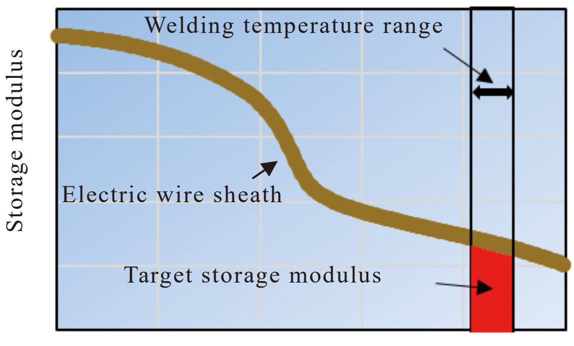


Fig. 4. Storage modulus required of the electric wire sheath and base sheet

We selected polyvinyl chloride (PVC), the same material as that of the wire sheath, for the base sheet from the viewpoint that both wires and the base sheet are subject to the softening and melting phenomenon and are bonded at the welding temperature. We decided to adjust the amount of plasticizer*8 to attain a lower storage modulus than that of the wires and avoid deformation of the wires. The storage modulus can be lowered by reducing the amount of plasticizer. On the other hand, increased softness leads to a decrease in the strength of the base sheet, resulting in lower peel strength. To prevent the deformation of the wires and ensure the peel strength at the same time, we fabricated prototype samples with different amounts of plasticizer and conducted evaluations (Fig. 5).

As a result, we determined the amount of plasticizer that could ensure the peel strength and prevent the deformation of wires at the same time, while attaining a wide range of welding conditions for stable quality and manufacturing.

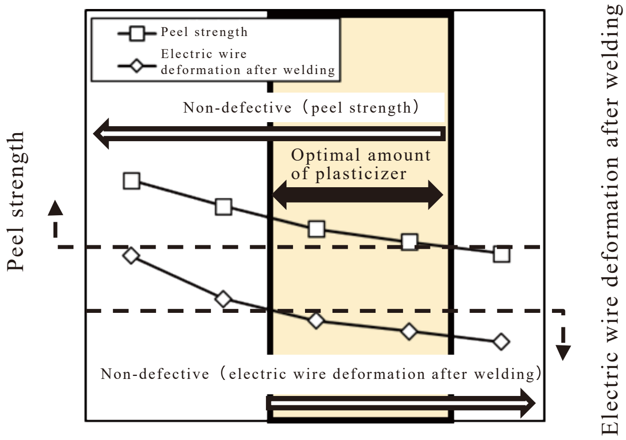


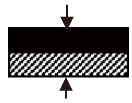
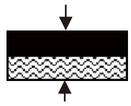
Fig. 5. Welding characteristics of PVC depending on the amount of plasticizer

4-2 Additional functions to the base sheet

Wiring harnesses must have the following protecting functions: tensile strength to prevent breakage of the base sheet when installed in vehicles, wear resistance to protect the wires from interference with the surrounding parts in the in-vehicle environment, hammering sound resistance to suppress the interference sound, and light weight. To reduce the man-hours required for assembly by shaping wiring harnesses in advance, which is the satisfaction offered by the e-STEALTH W/H, we also worked on development to meet the requirement to keep the route shape.

PVC, which was selected for the welding characteristics between the wires and the base sheet, did not meet the requirements due to its softness. Thus, we decided to use composite materials (one of which was used as a reinforcing material) using different materials. Hard PVC, which is characterized by high tensile strength, and polyethylene terephthalate non-woven fabric (PET non-woven

Table 2. Protecting functions and keeping of the route shape by using a reinforcing material

Configuration of the base sheet	Protecting functions				Keep of the route shape
	Tensile strength	Wear resistance	Hammering sound resistance	Mass	
PVC only 	Poor	Poor	Poor	Good	Poor
PVC + Hard PVC (reinforcing material) PVC  Hard PVC	Good	Good	Poor	Poor	Good
PVC + PET non-woven fabric (reinforcing material) PVC  PET non-woven fabric	Good	Good	Good	Good	Good

fabric), which was considered to absorb the hammering sound like a cushioning material when an air layer was provided from the viewpoint of ensuring hammering sound resistance, as candidate reinforcing materials to conduct evaluations. The results are shown in Table 2. The protecting functions and the requirements to keep the route shape were met by selecting the PET non-woven fabric and developing a technology to laminate with PVC.

The establishment of lamination technology has made it possible to equip various functions to the base sheet. This is expected to improve the added value.

5. Satisfaction Achieved by Installing the e-STEALTH W/H in Vehicles (Roof)

5-1 Increase in the interior space and minimization of the routing distance

Previously, the space required for routing of a wiring harness assembly was secured between the body and the headliner.*9 The e-STEALTH W/H has made it possible to reduce the routing space between the body and the headliner due to its flat structure. This is expected to increase the interior space by offsetting the headliner in the height direction.

In case that the routing space was narrow between the body and the headliner, conventional wiring harnesses were bypassed to locations where the space was available for routing. On the other hand, the e-STEALTH W/H, which is characterized by a flat structure, enables routing in the space that could not be used for routing due to the diameter of a conventional wiring harness. The routing distance can be minimized as shown in Fig. 6. This is expected to shorten the wires required and reduce the mass of wires.

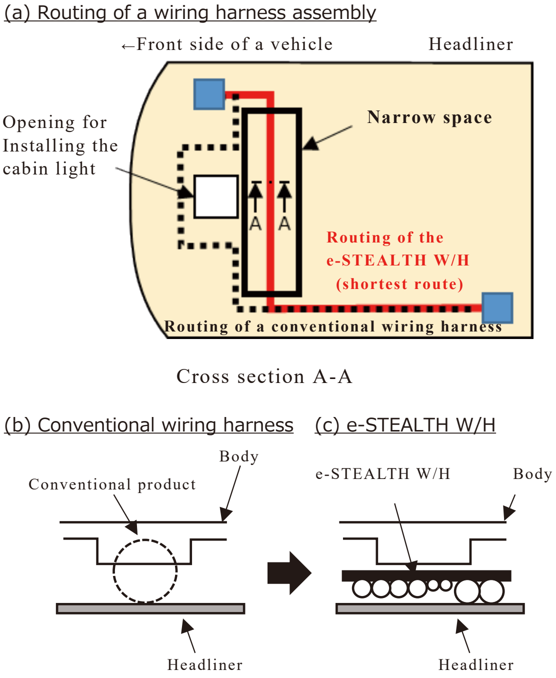


Fig. 6. Minimization of the routing distance

5-2 Reduction in man-hours required for assembly

Conventional wiring harnesses were sometimes entangled when unpacking, necessitating work to untangle them. It was also necessary to check the route direction, which could not be determined at a glance, before assembly.

On the other hand, the e-STEALTH W/H is not entangled when unpacking because the shape of the wiring harness is kept due to the strength of the base sheet, enabling immediate deployment to the desired route. This is expected to reduce the man-hours required for assembly (Photo 1).

In the future, wiring harnesses that keep their shape, like the e-STEALTH W/H, are expected to be installed in vehicles automatically.

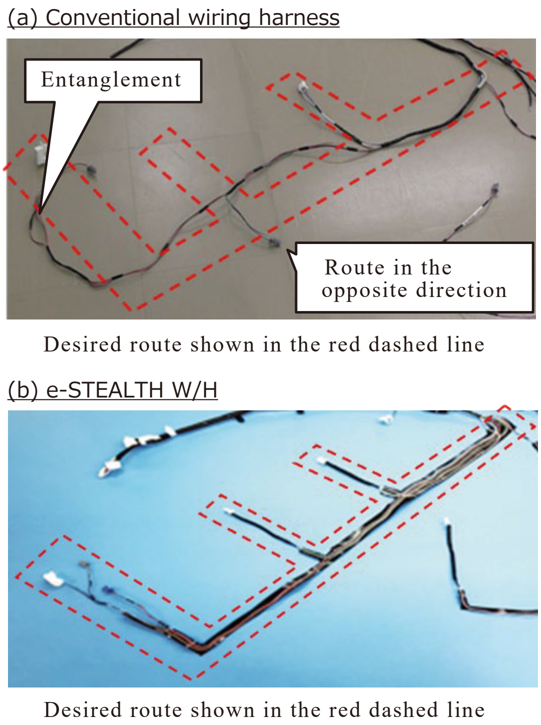


Photo 1. A conventional wiring harness and the e-STEALTH W/H after unpacking

6. Conclusion

We have succeeded in increasing the interior space by developing a flat wiring harness using automotive wires that meet the in-vehicle requirements and in achieving local production for local consumption by improving the automation rate. The characteristics of the e-STEALTH W/H are summarized below.

(i) Improving the automation rate to about 50%
(ii) Increasing the interior space (height of the wiring harness reduced by about 50% from the conventional product)
(iii) Minimizing the routing distance
(iv) Reducing man-hours required for assembly

We will open up the new possibilities of manufacturing by further improving the automation rate and promoting the automated installation of wiring harnesses.

We will also enhance the added value of wiring harnesses by adding new functions to the base sheet.

• e-STEALTH W/H is a trademark or registered trademark of Sumitomo Wiring Systems, Ltd.

Technical Terms

∗1 Wiring harness: A set of electric wires that electrically connects electronic parts and electrical equipment installed in vehicles, copiers, and printers, and relays the transmission of power and information between such components. It mainly consists of electric wires, protection materials, and clamps. Electric wires that make up a wiring harness have different functions, such as power supply and signal transmission.

∗2 Local production for local consumption: A practice to manufacture and consume products in the same area.

∗3 Flexible flat cable: A thin, lightweight flat cable with thin, flat conductors arranged next to one another and sandwiched by insulation films at the top and bottom.

∗4 Flexible printed circuit: Conductive materials arranged on a thin, flexible substrate in the shape of a line.

∗5 Ultrasonic horn: A device that comes into direct contact with a fusion target to transmit vibration.

∗6 Softening and melting phenomenon: A phenomenon where the ultrasonic vibration energy generates heat inside a fusion area to bond fusion materials

∗7 Storage modulus: Hardness of a viscoelastic body calculated based on the distortion curve and in-phase components.

∗8 Plasticizer: A generic term of substances added to certain materials to impart flexibility and elasticity.

∗9 Headliner: A ceiling lining material that has functions to absorb and insulate noise in the cabin and insulate heat from the roof.

Reference

(1) Sumitomo Group Public Affairs Committee,Social Issues addressed by Sumitomo-Compass for the Future- Sumitomo Wiring Systems×Local production for local consumption Local production of wiring harnesses for local consumption Automated manufacturing targeting both commercial success and resolution of social issues https://www.sumitomo.gr.jp/english/act/social-issue/sws/

Contributors

The lead author is indicated by an asterisk (∗).

H. NOMURA*
• Assistant Manager, Auto Networks Technologies, Ltd.

H. MIZUNO
• Group Manager, Auto Networks Technologies, Ltd.

K. KOU
• Assistant Manager, Auto Networks Technologies, Ltd.

T. KABA
• General Manager, Sumitomo Wiring Systems, Ltd.

J. SHIRAKAWA
• General Manager, Sumitomo Wiring Systems, Ltd.