Development of Flexible Flat Cable Harnesses for Automobile Roof Modules

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ABSTRACT There has in recent years been a marked trend in the automobile industry toward modular construction, and each manufacturer has applied a variety of approaches in the effort to reach a solution. As a parts manufacturer, Furukawa Electric has come to grips with this trend and is proceeding with the development of more effective modular elemental parts. Specifically we can anticipate that wire harnesses, which have traditionally taken the form of bundles of conductors, will take on a flat profile, and we have for some time been proceeding with study and development work. In the work discussed here we have developed flat harnesses for use with flexible flat cables (FFCs), and succeeded in using them in vehicles. The adoption of the flat harness profile greatly reduces the use of protective parts and gives greater routing freedom, but the cost of parts goes up and connecting problems arise. The point is how to reach solutions, and by solving these problems and launching mass production we were able to gain the technical expertise to derive specifications responsive to vehicle requirements and develop manufacturing equipment.

1. INTRODUCTION

As automobiles have become more sophisticated, harnesses have, through multiplexing, junction boxes and electronic control units in the body, seen a reduction in wiring, and advances have been made in the downsizing of wires using CAVUS ultra-thin low-voltage cables for automobiles. Harnesses are, however one of the products that has undergone no major change in the last 50 years or more.

There is, meanwhile, a trend favoring rapid introduction of structural modules and integration, so that from the standpoint of the structure of the vehicle as a whole it is essential that changes be made in the configuration of the harness.

2. CONFIGURATION OF HARNESS REQUIRED

The higher sophistication of the motor vehicle in recent years has meant an explosive increase in the number of circuits it contains. It is not at all unusual today for a vehicle to have upwards of 2,000 circuits.

Since harnesses take the form of bundles of conductors secured by tape their dimensions vary greatly and it becomes inevitable that dimensional tolerances for them be an order of magnitude greater than for other structural components. One way to assure that there is no problem even if they interfere with other parts is to cover them with tube-like protectors, but this just makes the harness even more bulky. What is needed is to form them with a dimensional accuracy that is as good as that of other parts.

A means used in the past to solve the problem of forming with increased dimensional accuracy was the use of a "forming protector". However such protectors and forming components are a waste of both money and weight from the standpoint of the harness's function of providing electrical conductivity.

One concept that is fundamental to solving these problems may be stated, "Forming without waste a harness that is without form = make it parasitic on objects having form".

3. THE NEED FOR A FLAT HARNESS

Configurations that can made parasitic may be divided broadly into: first, those means by which the wires are mounted directly to a structural member having grooves that accommodate bundles of conductors; and second, those means by which the conductor is made as thin as possible and then either attached to or integrated with the structural member.

The first of these is possible with the conventional configuration, and is applicable even with large numbers of circuits. The second requires a flat-type conductor configuration and the number of circuits is limited, but it has the advantage that there is basically no need to secure a route for the harness.

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In the work reported here, a roof module harness for FFCs using flattened conductors has been accepted for the Toyota Alltezza.

4. HOW THE FLAT CONFIGURATION WAS ACHIEVED

One can imagine flat-type conductors having a variety of configurations. These may be divided broadly into two types: first, the "circuit board type" in the form of a surface; and second, is the continuous "cable type".

Typical of the first is the flexible printed circuit (FPC), for which fabrication techniques that may be mentioned as most typical are a) etching and b) printing, although the authors have also considered c) shearing, d) plating, e) laser cutting, f) ultra-high speed routering, g) simplified press forming, and so on.

Since all of these are circuit board types, however, their major disadvantage is that when a large area is taken up by a harness, etc. yields are extremely poor and costs are high.

With respect to the second type, we think not only of FFCs, having flattened conductors, but of conventional flat cables, in which single cores or twisted conductors are laid out flat and extruded or bonded.

These characteristics allow manufacture in long, continuous lengths, and therefore make for higher productivity and improved yields, and provide a solution to the problems of the first type. On the other hand, in actual use it is necessary to subject them to further processing, by bending, etc.

In this work we selected an FFC with flattened conductors both in an effort to reduce thickness to the maximum extent possible, and in recognition of the future integration of auxiliary equipment functions.

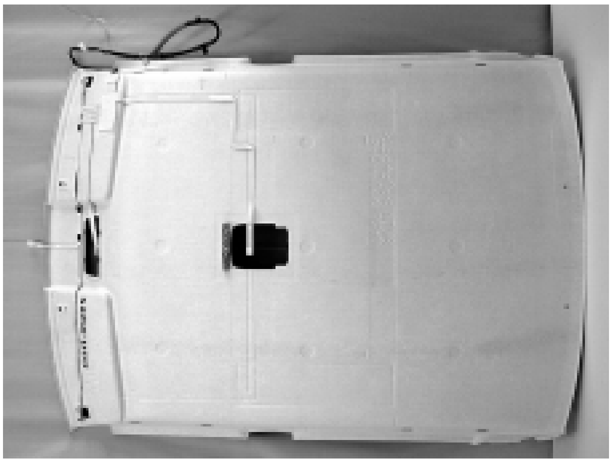


Photo 1 Complete roof module.

5. DEVELOPING THE FFC HARNESS FOR ROOF MODULES

5.1 Objectives

The FFC harness the development of which was described in the preceding section was conceptually congruent with the roof module being planned by Toyota Motor Corporation, and it was decided to proceed with a

Table 1 Specifications for roof harnesses.

Specification	Auxiliaries				
	MAP LP	S/R SW	VTYLP	DOME	EC-MIR
Japanese normal roof	○			Small	
Japanese sliding roof		○		Small	
Japanese normal roof ab	○		○	Small	
Japanese sliding roof ab		○	○	Small	
Left-hand drive normal roof	○		○	Small	
Left-hand drive sliding roof		○	○	Small	
Left-hand drive normal roof c	○		○	Small	○
Left-hand drive sliding roof c		○	○	Small	○
Left-hand drive normal roof d	○		○	Large	
Left-hand drive sliding roof d		○	○	Large	
Left-hand drive normal roof cd	○		○	Large	○
Left-hand drive sliding roof cd		○	○	Large	○
European/Australian normal roof e	○		○	Large	
European right-hand drive sliding roof e		○	○	Large	
Australian sliding roof e		○	○	Large	
European/Australian normal roof ce	○		○	Large	○
European right-hand drive sliding roof ce		○	○	Large	○
Australian sliding roof ce		○	○	Large	○

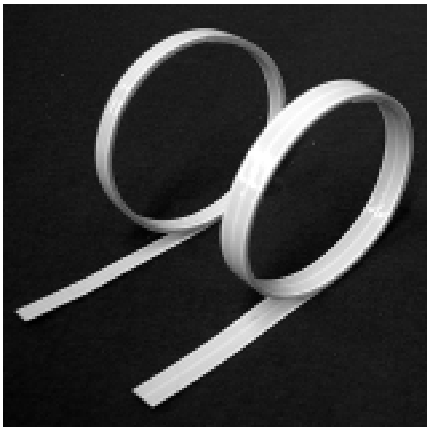


Photo 2 FFCs.

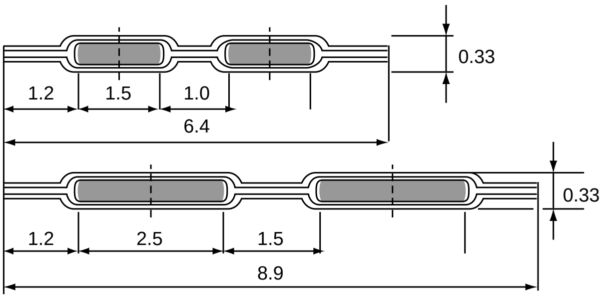


Figure 1 FFC dimensions.

joint development. At that time Toyota Motor was carrying forward a study on the use of a roof harness module using an ordinary wire harness for a model other than the Alltezza, for which a model change resulted in a change in the body configuration, so that harness routing could be secured. The Alltezza was given model year improvements so major changes in the body were not approved, so that with an ordinary wire harness, there would be parts that seriously interfered with the body. The fact that a slim profile was the prime advantage of the flat harness spurred them to further consideration of Furukawa Electric's FFC harness.

5.2 Overall Specifications

Photo 1 shows the roof module in its entirety, and Table 1 shows the product line-up and the specifications.

At the first stage of development it was proposed to use FFCs throughout, with the exception of circuits in the sliding roof. However with the introduction of curtain shield airbags the minimum space for the accommodation of the harness in the front pillar was only 12 × 12 mm. Thus the FFC, because of its width, could not be used and ordinary wires were used in the front pillar, resulting in the co-presence of both ordinary wires and FFCs.

5.3 Component Parts

With the assumption that the FFC would be generally applicable, allowing it to serve as a replacement for conventional wires, we adopted specifications with a strong bias on the side of safety (see Photo 2 and Figure 1).

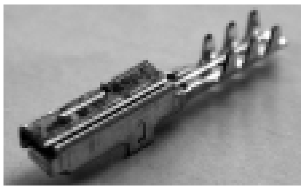


Photo 3 090 female terminal.

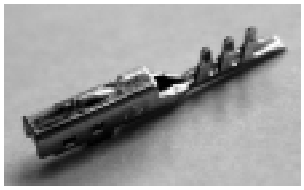


Photo 4 040 female terminal.

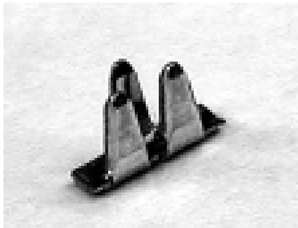


Photo 5 Cross-joint terminal.

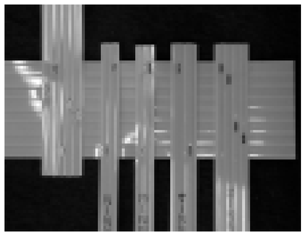


Photo 6 Cross-joint.

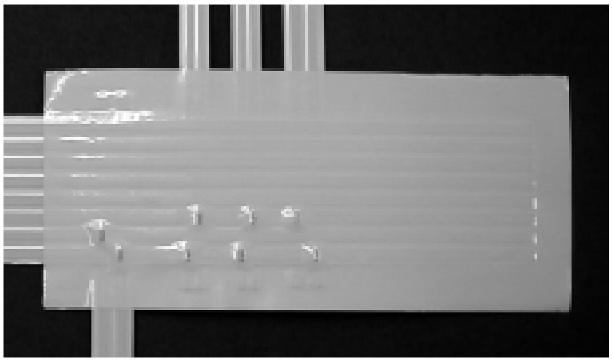


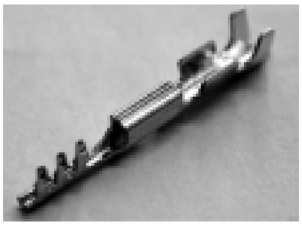
Photo 7 Cross-joint after lamination.

With the terminal connectors there was the matter of the timing of their introduction, so it was decided to adopt general-purpose connector interchangeability, to assure interchangeability with conventional auxiliary equipment. The housings were also such that conventional connectors could be used without modification.

Terminals were newly developed for FFCs. For connection with the FFCs, a new concept known as piercing was introduced, assuring the electrical and mechanical stability of the connection. Two sizes were used: 2.3 (090, see Photo 3) and 1.0 (040, see Photo 4).

For splices, a cross-joint terminal was developed to connect two FFCs overlaid in a cruciform configuration. Piercing technology was also used here as in terminal connection (see Photos 5 and 6).

So as not to sacrifice the advantage of a slim profile, the cross-joints were not protected by a case, etc. but were insulated by aligning and laminating the cross-joint with films from above and below. In addition it was possible by this method to obtain a simplified water-proofing effect (see Photo 7). Because of the need to connect wires to FFCs, a wire-to-FFC joint terminal (WF), with piercing and crimping on both ends, was also developed, as will be described in the next section (see Photos 8 and 9).



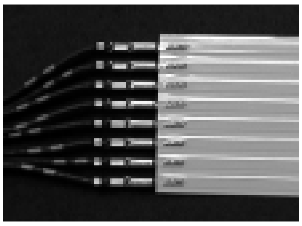


Photo 8 **Wire-to-FFC joint terminal (WF).**

Photo 9 **Appearance after connection.**

The basic idea behind connections for the FFC was to allow terminals to be fitted to the FFC without removing its insulation.

5.4 FFC Harness Configuration

For normal roofs, a mixed configuration was used, with FFCs attached to the roof and ordinary wires accommodated in the front pillar. The WF terminal was used to connect the FFC to the wires, and was accommodated in a WF holder protecting short-circuiting between terminals, and a saving in space compared to the conventional wire harness-to-wire harness connector was also a consideration.

The points of differences in sliding roof specifications from those for the normal roof are that the sliding roof switch and sliding roof motor circuits use an ordinary wire harness, and that FFCs and wires are present in the roof portion.

5.5 Problems of Use in Vehicles, and Measures Taken

Preconditions were the fact that, as a minor change, it would obviously not be possible to make major changes in the body, etc., and, with respect to electronic components, mass-produced parts were to be used without change, so that no change in circuit position for electronic components was possible.

A requirement was also made that mass-produced connectors be used so that they could be used in common with wires and FFCs. This in itself was a major theme in the development process, but conversely it was also possible to establish the elemental technologies that were an indispensable step in FFC development.

In terms of routing, wires are attached to the roof, so that the route can be shorter that with the conventional configuration in which they are attached to the body. On the other hand for the circuit leading to the vanity mirror lamp, it has conventionally been possible to have a connector emerge from an aperture on the body but since the harness was attached to the roof head lining, the circuit is fastened in together with the lining, sandwiched in the space between the body and the sun visor stay. With conventional wires such a configuration cannot be achieved, making it necessary apply some process such as to form an indentation in the body.

In the case of the FFC, even if sandwiched in it has no effect, and no change in the body is required. Specifically the brace of the header panel has a major effect on strength and unnecessary irregularities have a major effect on its performance, so that a configuration like the FFC offers major advantages.

The means by which the FFC is fixed to the roof is common with other models that are running with the process for attaching the roof head lining of the Alltezza, so it was handled by applying two-sided tape over the whole surface. The FFC has good adhesion properties, and, unlike conventional wires, is flat, making the adhesive area greater and resulting in an excellent bond. The FFC has no left-right bend and snaking does not occur so that if the reference position shifts, the shift persists to the end. The process of attaching was therefore studied by all those involved based on a full understanding of these properties.

6. MANUFACTURING THE FFC HARNESS

The manufacture of harnesses using FFCs was also caused to be extensively changed from that of conventional wire harnesses.

The basic objective was to change from the traditional manual processes to processes using automated machines.

Also the concept of completely single-unit processing that has been conventionally practiced was continued, with computers controlling of product numbers batch by batch, with production being order-driven, and carried out on a just-in-time basis.

6.1 Cutting and Bending of FFCs

Since with FFCs excess length cannot be absorbed, the accurate cutting and bending are of great importance. Accordingly FFCs were bent automatically at the same time as they were cut.

6.2 Trimming

Once the FFC has been cut and bent, it is then trimmed--a process that involves making slits between conductors at the ends. This means insertion into the conventional housing, and is practiced to avoid partitions between cavities.

6.3 Piercing

Since piercing must be carried out precisely in the center of the conductor, its position is detected. The process known as piercing is virtually the same as conventional crimping or insulation-displacement connection. The FFC that has been pierced is then terminal-inserted in the housing.

6.4 Splices

The cross-joints are points at which FFCs intersect, and require that terminals be driven in at the intersection. To do this each FFC is fixed to a single flat jig, restricting the position and forming a splice. After terminals have been driven in at all splices they are sandwiched between upper and lower films and heat sealed.

6.5 Connections to Wires

As was described above, the harnesses for pillars use conventional wires, and for this reason connections between FFCs and wires are made. Sub wires are manufactured by automated machines, and the point of connection to an FFC is also automatically set on a jig once the wire-side is crimped.

The jig used for the cross-joints is then shifted as is to the wire connecting machine, and piercing is carried out.

6.6 Finishing, Testing and Shipment

Finally the work is finished, focusing on the wires, a continuity test and visual inspection are carried out, and the product is shipped.

Since here FFC length is already assured by the equipment, dimensions are not checked on the assembly stand.

After passing through these process steps, the FFC harnesses are complete.

7. ANTICIPATING FURTHER DEVELOPMENTS

These roof modules using FFCs will not be confined to the Alltezza, but should be extended to other models in the future.

A cost comparison between wire only and FFC only, however, shows that it is not yet competitive, and as things stand now savings in cost can are found only in the reduction in protection due to the stability of configuration and the reduction in line length due to use of the shortest routes. In future, there will obviously be further reductions in the cost of the FFC itself, production processes will be revised and connectors reappraised. There are many avenues that must be pursued, such as design revisions suited to the FFC.

Modification for larger current and finer pitch are also under consideration not only for the roof modules, and ways of use that take advantage of the features of the FFC will be extended to all components.

Further, harnesses can also in the future be provided, for example, with "integration of termination parts" such as unitized switching functions, and with the inclusion of some joint-box and electronic control unit functions by "surface mounting technology", and it is thought that this, in itself, will have a variety of functions. With this in view we intend to proceed by utilizing the advantages of the flattened conductor.

8. CONCLUSION

This technology has been tied in with mass production, but this is not the end.

This achievement is only the first step to methods of changing harness configuration; further developments must be made. And not all will take the configuration of the FFC; each must have its own configuration using appropriate materials in the appropriate place.

On the other hand there is an urgent need for slim-profile solutions like the FFC, and advanced development must be carried out so that it can replace conventional wires with significant advantages in all areas, including cost, design, and quality.

Finally the authors would like to take this opportunity to express their deep appreciation for the great assistance offered in this work by the personnel concerned at Toyota Motor Corporation and Kanto Auto Works Ltd.

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