Development of Wire Harness Modules

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ABSTRACT In developing a wire harness for the completely new model Land Cruiser of Toyota Motor Corp., a major technological revolution is being carried out to overcome the problems with current designs and to automate wire harness manufacture. The aim is to improve ease of assembly to the vehicle, raise productivity, and increase recycling potential in line with anticipated future trends. These harnesses consist of a single type of wire--one color, one size, and went into volume production in January, 1998. An overview is given of the development of the new harnesses.

1. INTRODUCTION

Wire harness, the wiring and power distribution system for the transmission of electric power and signals for automobiles, has improved in many important respects in these few years. Although the increase in the number of circuits as well as the weight and size of wire harnesses repeatedly occurred at the time of model changes, such advanced technologies as signal sharing and electrical multiplexing transmission have appropriately dealt with this increase, eventually realizing the reduction in the quantity and size of wires.

In terms of the production process of wire harness consisting of wire cutting and terminal crimping, manual terminal crimping and manual cutting, wire intermediate jointing, temporary assembly (sub-assembly), assembly, electrical tests, and visual inspection, automation of the jointing process and thereafter has been in delay.

On the other hand, social environments have changed to influence wire harness technology development considerably. For example, young labor has decreased year by year making improvement of automation and work efficiency in the assembling process inevitable for car manufacturers. Moreover, wire harness has been one of the most difficult components to be recycled, because it takes much time to dismount at the time of vehicle dismantling, resulting in high recovery costs.

Against this background, to start the development program of the wire harness for a full new model land cruiser of Toyota, we undertook to design a novel wire harness (hereafter called W/H module) doing efforts to improve its mountability onto vehicles as well as productivity and recycling potential.

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2. DESCRIPTION AND OUTLINE OF DEVELOPMENT OF W/H MODULE

2.1 Description and Features

Table 1 describes the W/H module with such design factors as the number of circuits, of joints, of parts types, wire, and connector together with features such as production method. Photo 1 shows its appearance.

Table 1 Description of the W/H module with design factors and features

Item	Contents	Types	Quantity
Description Number of circuits			140 ~ 280
Number of joints			0
Number of types	Right side steering	3	
	Left side steering	4	
	Total	7	
Wire	CAVUS 0.5mm^2	1	
Connector	040F	14	45 ~ 50
Terminal	040F	1	280 ~ 560

Item	Contents
Features Production method	Full automated sub-assembly using automatic insulation-displacement sub-assembly machinery
Jointing method	Joint box and meter are bulk jointed by bolt fastening using assembling-connector

Table 2 Requirements and corresponding measures obtained by analyzing the present situation

		Many connectors and wires	Poor workability	Many terminal post-fitting	Many joints	Poor circuit reliability	Expected effects: Quality	Weight	Cost
W/H manufacturer		◎	◎	◎	◎				
Vehicle assembly line		◎	◎	○	○				
Quality information		○		○	○	○			
Place of occurrence / Point at issue / Measures									
Circuit	J/B integration			○	○		○	○	○
	Fire hazard measures					○		○	○
Route	Early securement of optimum route		○	○			○	○	○
	Optimum division	○	○	○			○	○	○
Configuration	Reduction of types						○		
	Consideration on mountability	○	○	○			○	○	○
Production method	Production at W/H manufacturer	○		○	○		○	○	○
	Optimization of sub-assembly	○		○	○		○		○
	Innovation of production system		○				○		○

⇔ Construction of development targets

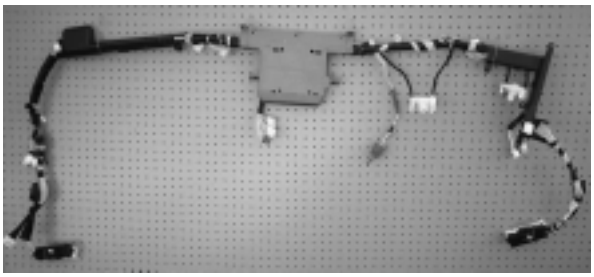

Photo 1 W/H module

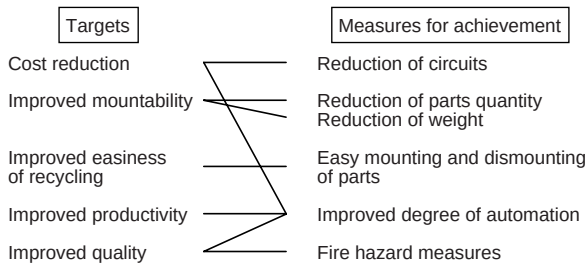

Figure 1 Relationship between targets and measures

2.2 Analysis of Present Situation

We have analyzed the present situation of wire harness for its quality information, mountability onto vehicles at assembly lines, and productivity at manufacturing floors, enabling to gain a comprehensive grasp of many points at issue as shown in Table 2. Subsequently, we have stratified the points at issue into the layers of circuit, route, wire harness figure, and production method thus deriving corresponding countermeasures, which are restructured to construct the development targets.

2.3 Development Targets

The targets of the current program were to develop a W/H module with low costs and improved recycling potential in addition to such improvements as were derived from the present situation analysis: mountability, productivity, and quality. The relationship between each target and its measures in the design process is shown in Figure 1.

3. DEVELOPMENT OF W/H MODULE

3.1 Unification of Wires

In conventional wire harness production, hundreds of varieties of wires having different sizes, kinds, and colors of core and insulation are cut and terminal crimped, subassembled, and assembled to make wire harness products. Thus, the extraordinary variety of wires has been a major factor that hinders the automation of wire harness production. Unification of wires, desirably into only single type of wire, was targeted in the current development program, aiming at realizing full automation of processes ranging from cutting to sub-assembly. To be more specific, downsizing of wires was investigated by means of conversion into signal circuitry and reevaluation of common power sources, reducing the variety of wires into two types: 0.5 mm^2 and 0.3 mm^2. These were subsequently unified to 0.5 mm^2, taking cost reduction of automatic sub-assembly machinery and productivity into account. Colors

of wires were also unified into a single color, but identification marks were decided to be laser marked on the end of wires taking serviceability at market into consideration. In this way, circuit design environments for the single sized and single colored wires were realized.

3.2 Unification of connectors

Connectors also have been hindering, like wires, automated production with their enormous varieties of several tens in the types of terminals, which expand to several hundreds when way number is included. We were in a position to unify connectors since we had unified wire sizes to 0.5 mm^2. We selected 040 connector (male tab width of 0.04 inch) which was the smallest applicable to 0.5 mm^2 wires, and furthermore changed the connecting method from crimping to insulation displacement so as to improve productivity on automated machinery. The unification to 040 connector enabled reducing the variety of terminals to 1, that of connectors to 6 for joint boxes, 2 for meters, in addition to 6 for standard types with pin counts of 2, 5, 10, 14, 18, and 22, totaling to 14. This resulted in a considerable simplification of the structure of automatic sub-assembly machines.

3.3 Elimination of Joints

Joints have been the foremost impediment to the automated production of wire harness products. Therefore, about half of the joints in the W/H module that amounted to about 100 were incorporated into the joint box connected to the W/H module along with into the ECU (electronic control unit aiming at wire reduction by concentrating the controlling functions around the instrument panel). The rest of the joints were incorporated into either of the two types of joint connectors (JC) of insulation displacement type provided afresh, thus eliminating all the joints. Figure 2 illustrates an example of joint elimination.

3.4 Sub-assembly

Conventionally, terminals that could not be inserted into a sub-assembly were to be inserted into a mating connector of another sub-assembly at the time of the latter's assembly, which impeded assembling productivity considerably. In the current development, the design permits all the terminals to be inserted at the sub-assembly process. Thus, selection of the connector between the joint box and the instrument panel ECU as well as changes of configuration and the efficient use of the joint connector resulted in realizing five types of sub-assemblies comprised of 30 to 80 circuits each.

Considerations in the design above mentioned --unification of wires and connectors, elimination of joints, and entire termination of sub-assembly-- enabled us to substantially advance in the automation of production. Figure 3 compares the conventional process with that of the W/H module, showing that the new process succeeded in integrating the processes ranging from cutting and terminal crimping to a portion of assembly into one: automatic insulation displacement sub-assembly.

3.5 Assembling-Connector

The reduction of connector quantity and the easiness of mounting and dismounting were also included in the design targets in order to improve mountability at the production lines of automobile manufacturers as well as easiness of recycling. Connection of the W/H module with the right and left joint boxes by means of the sub-assembly was seen to necessitate 6 types of connectors with 14 pin counts each, meaning an increase in the quantity of connectors. To cope with this, a new holder was introduced to make an assembling-connector, which enabled connection and disconnection by using a single bolt. This eventually reduced the connection of joint boxes at automobile manufacturers' lines to two, right and left, improving mountability and easiness of recycling. The connectors were made to follow the same specifications so as to reduce costs.

Furthermore, self alignment mechanism was adopted in the connection between assembling-connector and joint box as well as in the connection of meters, so that mountability at manufacturing lines would improve.

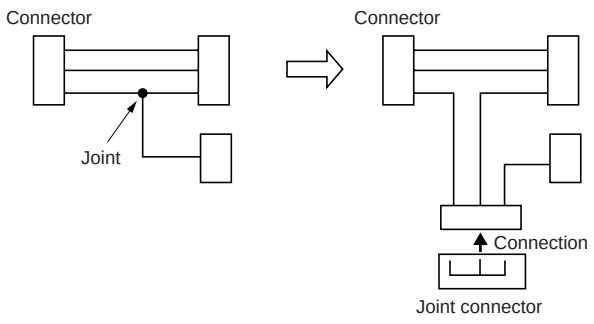

Figure 2 Example of joint elimination

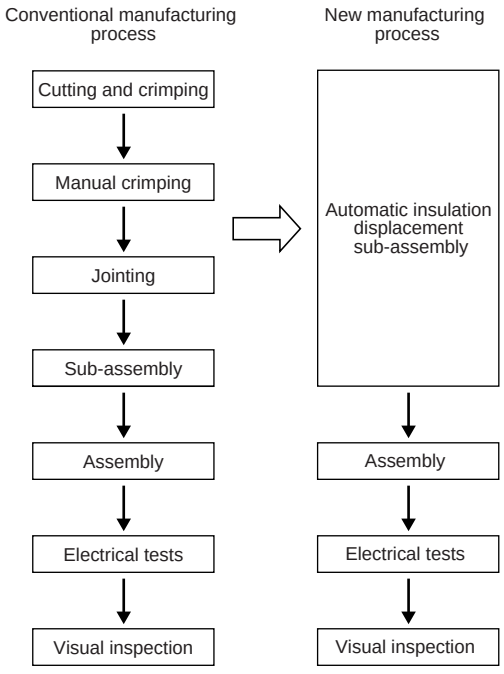

Figure 3 Comparison of production processes for the new and old harnesses

3.6 Variety Reduction

The variety of the W/H module was reduced as described below. Firstly, the arrangement of terminals in joint connectors was unified into one type, independent of the W/H module type. Conventionally, the arrangement was quite diversified according to the types of air-conditioners or meters, which varied depending on car grades and shipping destinations. Secondly, introduction of the W/H module technology suppressed potential cost increases to be caused by variety reduction. In conventional technology, in which variety reduction was done typically by adopting an upper grade specification, the reduction was impeded by cost increases of lower grade products with their specification of wide margin. The W/H module technology, as mentioned, enabled full automation of the processes ranging from cutting to a portion of assembly, thus reducing working cost per circuit to a level that promoted variety reduction further. As a result, the variety was finally reduced to seven, which would have been 50 to 60 in the conventional technology.

4. COMONENTS DEVELOPMENT

Components needed to realize construction of the newly developed W/H module will be described below.

4.1 Joint Box (JB)

Photo 2 shows the joint box for indoor, left cowl side use. It is a major component for the fully terminated sub-assembly with its functions of power distribution and others as well as accommodation of joints.

4.2 Instrument Panel ECU

Photo 3 shows the instrument panel ECU. It has various control functions such as prevention of battery run out and it accommodates joints for the W/H module. It is located in the W/H module, at the center cluster, considering serviceability.

4.3 Joint Connector (JC)

Photo 4 shows a joint connector with 22 pin counts. It was introduced, in addition to that with 14 pin counts, to accommodate the joints that overflowed the joint box.

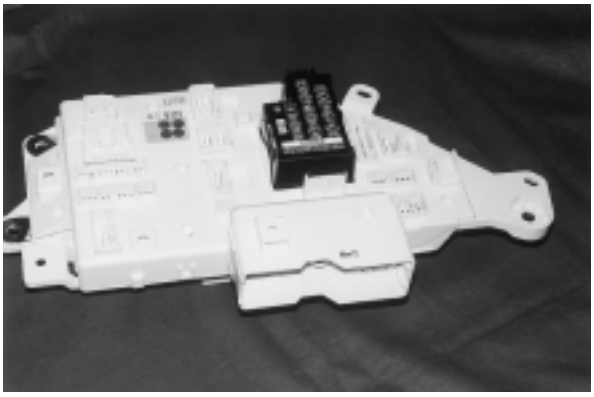

Photo 2 Joint box (JB)

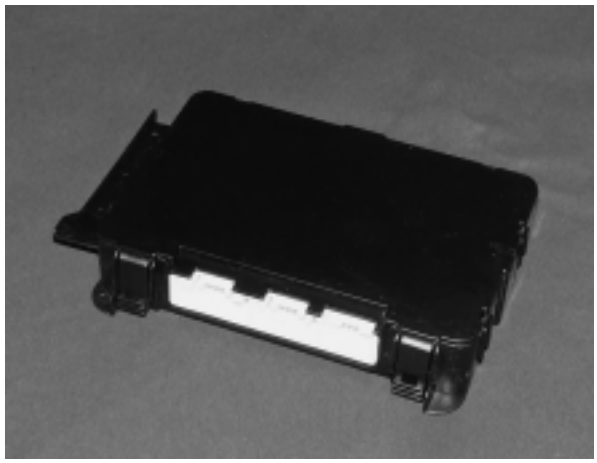

Photo 3 Instrument panel ECU

Photo 4 Joint connector (JC)

5. AUTOMATIC INSULATION DISPLACEMENT SUB-ASSEMBLY MACHINE

The automatic sub-assembly machine that had been previously developed was a small-scaled machine based on crimping jointing technology with its maximum working capability of 20 circuits. A large-scaled machine was needed anew to manufacture the W/H module that comprised, although just one type of wire and one type of insulation displacement connector were used, sub-assemblies of as many as 80 circuits at maximum; and we have been successful in the development of this new machine.

6. CONCLUSIONS

The development program of the wire harness for a full new model land cruiser of Toyota, which was carried out on an unprecedented scale for Furukawa, produced such precious outcomes as described below.

6.1 Establishment of Design Methodology for W/H module

We started studying the fundamental concepts in the autumn of 1994 and, through joint development with Toyota

lasting for three years, succeeded in large scaled modularization of the W/H module, thus establishing its design methodology.

6.2 Development of Novel Components and Facilities

We have developed such novel components as joint box, instrument panel ECU, assembling-connector, and joint connector this time, enabling ourselves to accumulate considerable amount of knowhow with varieties through the development cycle of design, prototype production, and on-vehicle evaluation. In terms of facilities, we have established technologies for sub-assembly machinery which is capable of dealing with large-scaled sub-assemblies with high speed.

6.3 Building of Development Infrastructure

In the course of this development program for entirely new technologies for Furukawa, we have been successful in fostering a number of engineers as well as in improving our organizational structure.

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