Development of the Furukawa Digital Assembly System to Support the Design of Wire Harnesses for Automobiles

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ABSTRACT We have developed the Furukawa Digital Assembly (DA) system to support the design of automobile wire harnesses (HIT system and FDA system). The DA system enables a great reduction in manhours for design, number of prototypes, and manhours for production preparation by utilizing 3D-CAD information from client automobile manufacturers linked to our present wire harness production design system. The key features are: (1) automatic determination of the branching direction on the assembly and/or jig board, hereinafter referred to as the production board and of the fitting direction of parts in the application of strain analysis technology; (2) layout support adjusted to the size of the production board; (3) examination of production board workability; (4) examination of operational workability; (5) productivity validation of the wire harness production line (process design); and (6) configuration calculation of the fitting condition of the wire harness to the vehicle.

1. INTRODUCTION

Three-dimensional design using 3D-CAD has become established over the last decade in the automobile industry. In the design of wire harnesses, which are primary automotive components, a rough configuration is determined from 3D data for the vehicle as well. However, wire harnesses are manufactured flat, as they are rather flexible. Accordingly, automobile manufacturers have employed two-dimensional 2D drawings using 2D CAD for wire harness design. Recently, however, automobile manufacturers are aiming at shorter development times in order to respond promptly to market needs, and they have a strong desire that suppliers provide early design examination.

In response to this, we have sought for greater efficiency, and upgraded in the application of strain analysis to part of the harness design work in the form of a 3D-to-2D conversion HIT System. In addition to a 3D-to-2D conversion capability, the present HIT system makes it possible to calculate the fitting configuration of the wire harness to the vehicle, and to examine each condition of the harness, both at production and when fitted to the vehicle.

The other development for the purpose of checking the production process is the FDA system, which enables examination of production board workability, operations, and process design.

We have built a system that supports and examines the operation promptly in a series of designs, with full utilization of simulation technology by linking the HIT system, CAD system, wire harness production design system and FDA system. This series of systems is called the DA Circle (Figure 1) and the whole system is known as the Furukawa DA System.

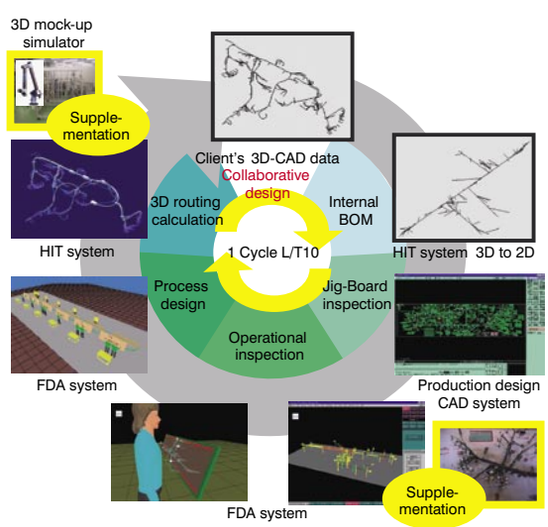

Figure 1 DA circle.

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2. FURUKAWA DA SYSTEM

The Furukawa DA system consists of the HIT System, Production design CAD system, and FDA system.

In the HIT system, which stands for harness information translation system, the configuration is converted in the process between the condition of the wire harness in the vehicle (3D configuration) and the condition at production (2D configuration), and calculation of the stress distribution of bending and distortion is performed under production requirements (3D-to-2D conversion and layout support on the production board (assembly drawing) and under fixture conditions (2D-to-3D conversion). The production design CAD system is capable of preparing for quotations and other form evolution, which require information output.

The FDA system, which stands for Furukawa digital assembly system, enables simulation of production board workability, operations and process design.

The following is an outline of procedures for the design of a wire harness.

1) The designer first converts a 3D wire harness configuration to a flat 2D configuration using the HIT system's 3D-to-2D conversion.
2) He draws a rough layout of the wire harness configuration on the production board using the production board design drawing (assembly drawing) layout support capability of the HIT System.
3) He designs details on the production board using the production design CAD system.
4) He initiates automatic drawing of a model on the production board and examines production feasibility and wire harness fitting.
5) He simulates production operation using a human model by using the FDA system's workability check.
6) He optimizes process design using the FDA system's process design check.
7) He converts 2D data for the wire harness product to 3D data to be fitted to the vehicle (for the use of the product), and compares and examines the design configuration data from the client using the HIT system's 2D-to-3D conversion.

In case of trouble in the process of the production board workability examination or workability check using the FDA system, or of 2D-to-3D conversion using the HIT system, the designer goes back to the production design CAD system and re-examines the production board design.

The series of operations described above enables a thorough examination of both the production feasibility of the wire harness and the workability of the vehicle configuration.

2.1 HIT System 3D-to-2D Conversion

The designer converts 3D data for the wire harness as a beam model into 2D data in the application of the finite element method under conditions of minimum strain. This system enables automatic calculation of the branching direction and the fitting angle to vehicle.

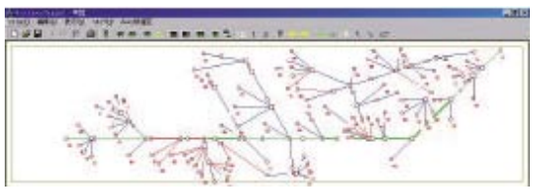

Figure 2 Typical layout support for a production board design drawing (assembly drawing).

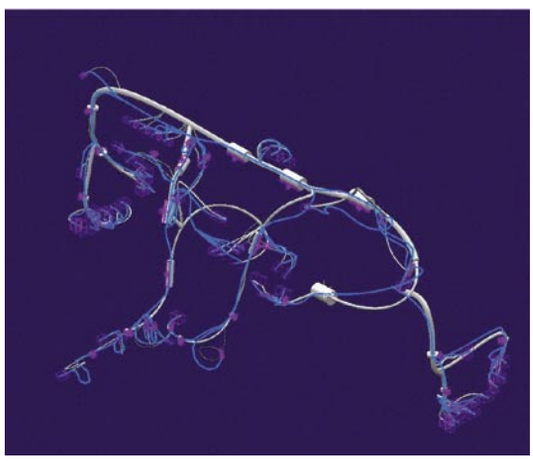

Figure 3 2D-to-3D conversion (superimposed images).

2.2 HIT System Assembly Drawing Layout Support

The designer lays the harness out on the actual production board, incorporating production requirements based on the results of 3D-to-2D data conversion and 2D design data from the client automobile manufacturer. Since not all the requirements can be fully incorporated at this stage, the designer needs to confirm and edit. However, the new system allows layout to be accomplished without using CAD, providing a user-friendly environment.

Figure 2 shows a typical layout.

2.3 HIT System 2D-to-3D Conversion

The method is analogous to 3D-to-2D conversion. Using the 2D configuration of the wire harness as a beam model, the system calculates the configuration of the harness to be fitted to the vehicle, applying the finite element method under the constrained conditions of position and orientation of the parts to be fixed to the vehicle.

Figure 3 shows the results restored by 2D-to-3D conversion, superimposed on the harness center line (blue line) of the design data, which are provided by the automobile manufacturer. This makes it possible to present the client manufacturer not only with a fitting configuration of improved accuracy, but also with more realistic results by providing additional information (testing function).

As Figure 4 shows, wire distortion is visualized and the reaction force is displayed from fixed components and the elongation by conversion data.

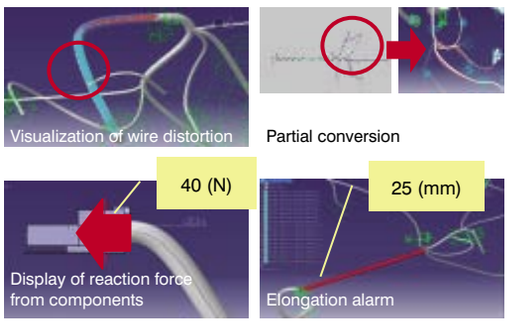

Figure 4 2D-to-3D conversion (evaluation function displayed).

2.4 FDA System Workability Examination on Production Board

This is a system that speeds up solutions to the past problem that data extraction was only possible in the production process using a 3D model. This system is a customized ENVISION 3D simulation system made by Delmia of U.S.A. Regarding its capability to validate workability on the production board, it automatically produces a 3D production model on the production board, validates the feasibility of actual production by checking interference, based on data on production board design developed by the production design CAD system.

In wire harness production, it is sometimes necessary to make harness products with different specifications on the same production board, thereby necessitating interference checking utilizing a jig, etc. This is followed by examination of the responsiveness to all the production set for the production board. This is the same as the case of operating jigs in the wire harness production process.

Figure 5 shows an example of examination of workability on the production board.

2.5 FDA System Workability Examination

Regarding the system's validating function, the system validates workability in the wire harness production process on the production board by means of simulation using an ENVISION/Ergonomics human model adjusted to the physical build of the operator engaged in harness production, allowing detailed items on working space and the operator's posture to be examined.

Figure 6 shows an example in which tape wrapping is examined.

2.6 FDA System Process Design Examination

This is a system that speeds up solutions to the past problem that data extraction was only possible in the production process using a 3D model.

The FDA system process examination is carried out by operating a customized QUEST 3D factory simulation system made by Delmia together with the ENVISION 3D simulation system. Utilizing validation of production board workability and operational workability on the production board, it identifies the best architecture and identifies problems on the wire harness production line, such as optimization of the production line in the development process, problem finding in line operations, and validation of time allocations.

Figure 7 shows an example of process design verification.

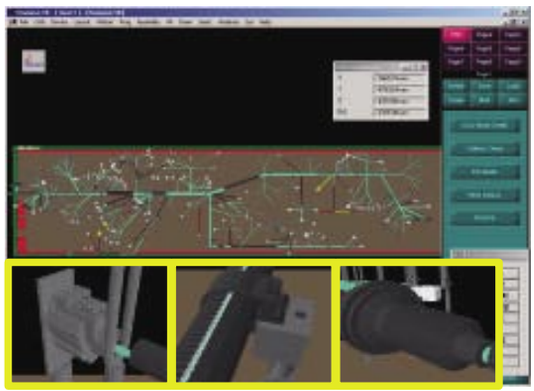

Figure 5 Consistency verification for production board based on FDA system.

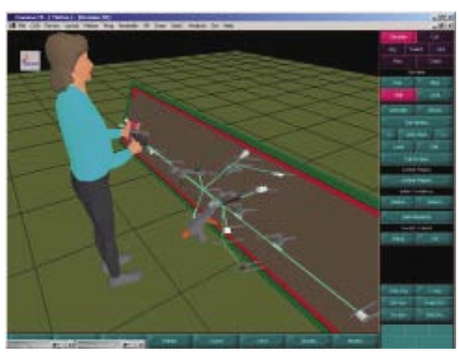

Figure 6 Workability verification based on FDA system.

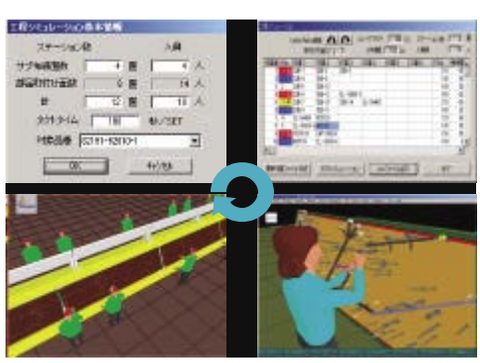

Figure 7 Process design verification based on FDA system.

3. EFFECT

As yet we have few examples of operations using this system, so that full-fledged examination of its effect lies in the future. At present, we expect that the development of its various functions will produce the following effects:

1) Effect of using the HIT system's 3D-to-2D conversion and production board drawing (assembly drawing) layout support: we expect 70 % reduction in the manhours required for production board drawing (assembly drawing).
2) Effect of using the FDA system workability examination of the production board: in the past, problems such as jig interference and shortage of workspace were not discovered until the prototypes of the production board and harness were actually built. The FDA system workability examination of the production board has made it possible to discover these problems without prototypes of the production board. This is a great advantage.
3) Effect of using the FDA system workability examination: as in 2) above, the workspace and workload can be examined without a prototype. A reduction in learning time can also be expected, as the production procedures can be visualized and are easy to learn.
4) Effect of using the FDA system examination of process design: this is as in 2) above regarding productivity of the whole production line (process design). It has been possible to support achieving the best line architecture and identifying problems without building a prototype. Also, as in 3), a reduction in learning time can be expected by utilizing it as operational instructions.
5) Effect of using the HIT system's 2D-to-3D conversion: in the past it was necessary to fit a wire harness prototype to a vehicle or vehicle simulator to examine the condition of fitting to the vehicle. Because trial fitting is very costly, as are the wire harness prototypes, the client automobile manufacturers are eager to reduce the number of prototypes required.

This system is not only for internal use by Furukawa, but is also useful as a solution for client manufacturers' desire to reduce the number of prototypes.

4. FUTURE DEVELOPMENT

The main issue for the future is to accumulate data through actual operations and fine-tune the system for further efficiency.

Among our challenges in terms of system development are:

- Improvement in 2D-to-3D conversion accuracy;
- Tracking the effect of layout on the production board;
- Improvement in production simulation accuracy;
- Expansion of production simulation coverage;
- Responding to new CAD systems of client automobile manufacturers;
- Promoting automation; and
- Involvement in design/production know-how.

We are committed to finding solutions to the above problems, as well as to reconfiguring the CAD systems of client automobile manufacturers.

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