

Development of System to Generate FE Models of Body-in-White

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ABSTRACT

A system to generate models for body-in-white analyses has been developed that reduces the number of man hours expended on the formulation of FE models for automotive body analyses. This system comprises a model management system and an automatic mesher. The model management system automatically registers the CAD models of body-in-white parts, data on the thickness and materials, and data on connections between parts, and can also manage the formulated FE models. The automatic mesher creates FE meshes from the registered CAD models. The new mesher provides more detailed reproduction of parts that affect calculation accuracy, including the shape of fillets, beads and flanges and spot welding connections, than the previous mesher. This has reduced the amount of correction required for the models.

1. Introduction

Large-scale automotive body analyses have recently begun to be widely used, and have contributed to reducing the time required for the development process by enabling performance to be evaluated with a high degree of accuracy before an actual vehicle is built. A preprocessor has already been developed that increases efficiency in formulating the FE models used in these large-scale body analyses, thus reducing the time spent on creating the models⁽¹⁾. An automatic mesher for use in generating FE models for body-in-white analyses has also been developed to make the process of generating FE meshes (hereinafter mesh) for various components more efficient^{(2) - (4)}.

However, a huge expenditure of man hours was still required for the collection of data on several hundred body-in-white components and the connections between them, meaning further increases in efficiency are needed to achieve still greater time savings in the development process. In addition, it was necessary to achieve more detailed reproduction of the shapes of components in meshes in order to increase the accuracy of the results of analyses,

and this would also necessitate an immense investment of man hours.

A system to generate FE models for vehicle body analyses, comprising a model management system able to automatically register models and an automatic mesher able to reproduce shapes in greater detail, was therefore developed to make operations more efficient.

2. Flow of Generation of FE Model

A body-in-white is made up of several hundred parts connected by welding and other means. These are reproduced by FE models to enable analyses to be conducted using the finite element method. Figure 1 shows the flow of procedures in generating the FE models.

First, data is collected on the components of the body-in-white. The information that is essential to generating an FE model is the CAD models of the components, data on thickness and materials, and data on connections between parts. The parts might be connected by spot welding, MIG welding or bolts, among other methods. Data on the combination and positioning of connected

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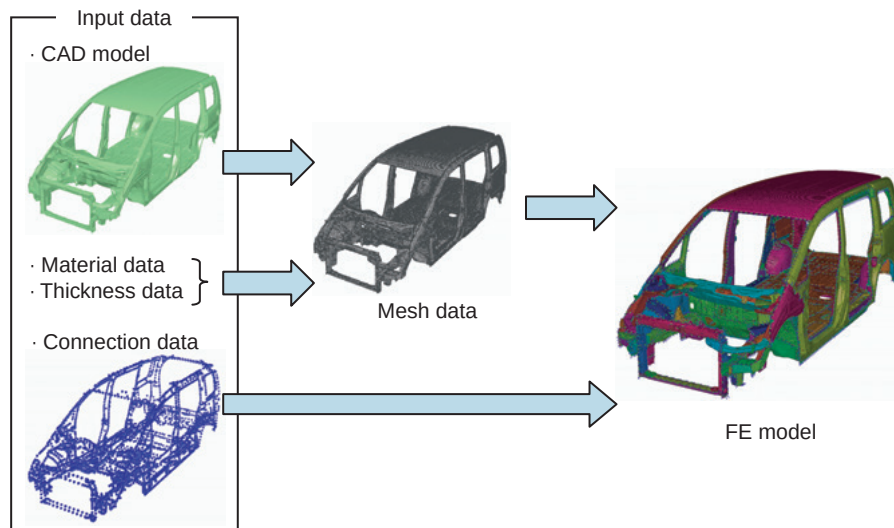


Fig. 1 Data flow of FE model generation

parts is also used.

Next, meshes are created from the CAD models of the components. Press-formed parts are reproduced using triangular and square two-dimensional elements. As the models are being generated, thickness and material characteristics are applied to the elements.

A preprocessor is then used to formulate FE models for use in robust, NV and crash analyses from the generated meshes and the connection data.

3. Issues Concerning the Previous Method

The aspects of generation of FE models for body-in-white analyses that required a large expenditure of man hours were examined.

3.1. Model Management

Although a DPM system⁽⁵⁾, which creates and manages digital mock-up data, was used to enable integrated management of the CAD models of the body-in-white parts and thickness and materials data required for generation of the meshes, a huge number of man hours were previously required to manually program the data for each of several hundred components.

In addition, connection data in technical drawings also previously had to be manually scanned and programmed. This also required a large number of man hours, as an entire body-in-white contains several thousand points of connection.

3.2. Mesh Generation

To achieve greater calculation accuracy, the meshes employed in vehicle body analyses are required to reproduce the original shapes in the CAD model in greater detail. Standard indexes, including warping, aspect ratio and angle, have been established for each solver to ensure element quality. Meshes are required to satisfy these element quality standards, because failure to do so may prevent calculations from being conducted or accurate results being obtained. Reducing the size of the elements generally increases the level of reproducibility of shapes and the quality of the elements, but this method also increases the number of elements, consequently increasing solver calculation time. To achieve detailed

reproduction with the minimum number of elements, it was previously necessary to manually program the edges of fillets, beads, and other elements along constraint edges. In addition, elements that did not satisfy element quality standards had to be corrected manually, and these manual operations also involved many man hours.

4. Development of Model Management System

A model management system was developed to increase the efficiency of the operations that had previously required a huge expenditure of man hours: CAD modeling of the body-in-white parts, collecting data on thickness and materials, programming connection data and generating the meshes. Figure 2 shows an overview of this system.

4.1. Parts Data Collection

The new system centrally manages the CAD models, the data on thickness, materials and connections, and the FE models formulated from the data. The system links to the DPM system, which registers the CAD models and thickness and materials data, enabling it to automatically collect the body-in-white parts data as a package. Even if the process of parts registration in the DPM system is not yet complete, the model management system is able to automatically collect data as parts are completed and to generate meshes.

4.2. Connection Data Collection

The development of a function for the transfer of data programmed in CAD models and other FE models enables connection data to be automatically programmed. When the connection data is incorrectly programmed, a summary for the specific area is output, enabling the programmer to determine and correct any flaws.

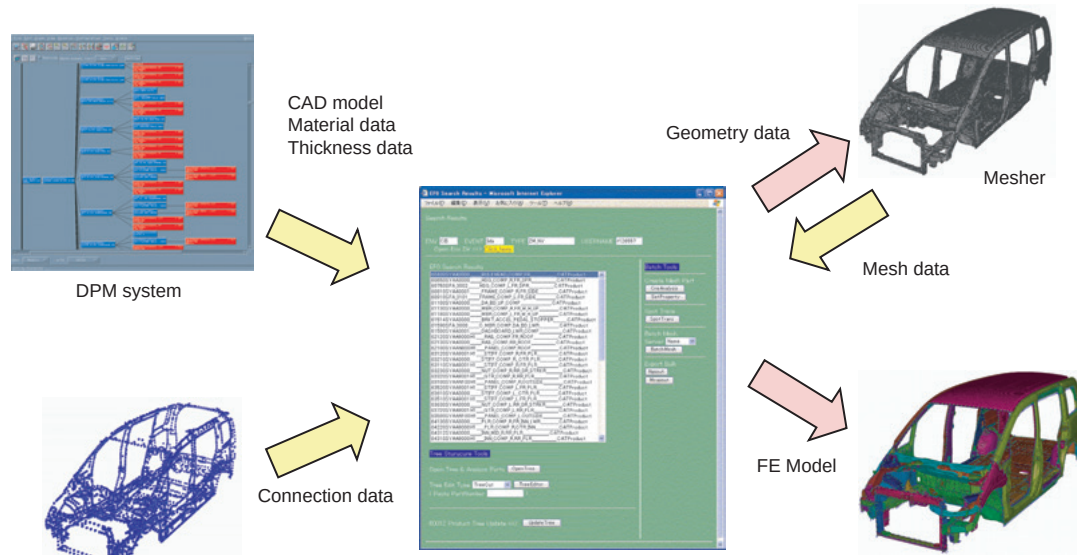


Fig. 2 System overview

4.3. Automatic Mesh Generation

The new system uses an automatic mesher (discussed below), enabling meshes to be generated from the registered CAD models in a single procedure. When the automatic mesher has completed a mesh, it outputs a summary report indicating the success or failure of mesh generation, element quality and other factors. On the basis of this data, the programmer is able to focus on correcting only meshes with flaws.

4.4. FE Model Output

The new system is able to output the generated meshes and the connection data as solver or preprocessor data, as required for robust, NV and crash analyses.

5. Modification of Automatic Mesher

It has become necessary to increase the level of reproducibility of components and the quality of mesh elements in order to increase analytic accuracy, but the previous automatic mesher was unable to automatically generate meshes satisfying these requirements. Modifications were therefore made to the automatic mesher.

5.1. Increased Detail in Reproduction of Fillets

Press-formed parts are generally composed of standard surfaces and the fillets at their boundaries. Reproducing the fillets is an important factor in reproducing the shape of parts using a mesh. However, fillets are not adequately reproduced by mesh when their width is less than the size of the elements. To enable automatic reproduction of this type of fillet, an algorithm was developed that can determine the fillet from the curvature of each face of the CAD model and other data, and automatically extract the edges of the boundaries. The fillet shape is reproduced in mesh by using these edges as constraint edges and aligning the edges of the elements with them. Figure 3 shows the results of applying this method. Depending on the shape of the face, the extracted edges may be in extremely close proximity, which has a negative effect on mesh quality. In this case, one of the edges is removed to reconcile detailed reproduction and element quality. Figure 4 shows the results of this process. This function ensures that constraint edges in close proximity do not produce meshes with a poor aspect ratio.

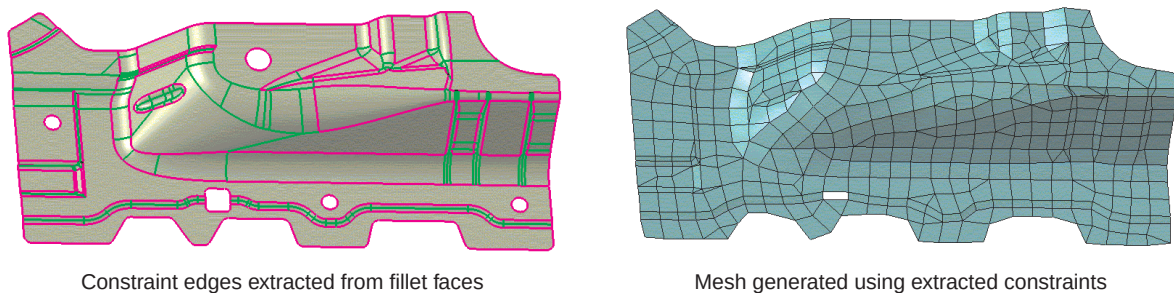


Fig. 3 Fillet representation

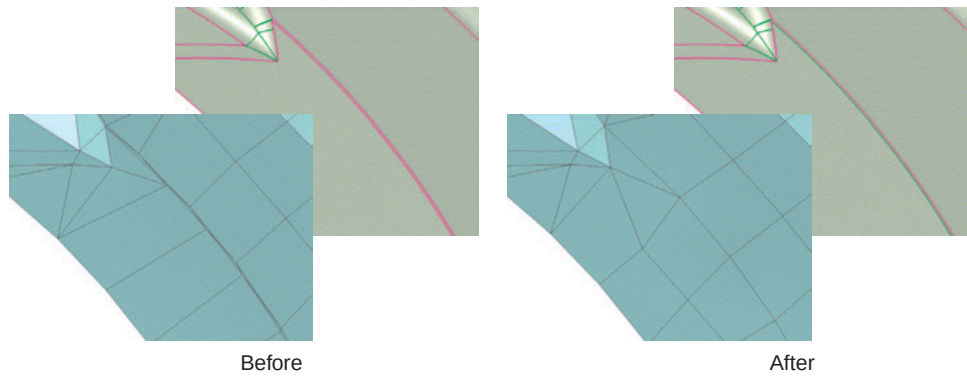


Fig. 4 Constraint simplification

5.2. Increased Detail in Reproduction of Beads

Bead shapes are generally made up of the type of faces shown in Fig. 5. Reproduction of the bead height is the important factor in reproducing beads in mesh. However, when the width of the bead is less than twice the size of the elements, only one layer of elements is used for the bead, and the height is not reproduced, as shown in Fig. 6. Even when the bead edge is set along a constraint edge to reproduce the height, there will be insufficient detail in the reproduction, as shown in Fig. 7. To enable automatic modeling of beads, an algorithm able to detect the shape of the bead from the configuration and curvature of the faces in the CAD model was developed. In addition, automatically forming a curve at the ridge of the bead (Fig. 8) and setting it along a constraint edge, enables automatic reproduction of the height of the bead in mesh, as shown in Fig. 9.

5.3. Generation of Spot Welding Pattern

The standard mesh pattern shown in Fig. 10 is generated to reproduce spot welds for stress evaluations of spot weld connections in robust analyses. The new mesher can automatically generate this standard mesh pattern at the points of connection shown in the registered connection data when generating meshes. Connection data is normally designed after completion of the connected parts, but in the new system, the meshes are formulated in advance and only the connections are remeshed as connection data is obtained.

5.4. Greater Detail in Reproduction of Convex Shapes

When a large element size is employed, the area of CAD models of convex shapes such as corners of flange not covered by the mesh increases. When there are spot welds in the model (Fig. 11), the mesh does not cover the spot weld connections, and connection elements are not generated (Fig. 12). This has a significant effect on the generation of specified mesh patterns at spot weld connections, particularly for robust analyses. A convex shape recognition algorithm was developed to ensure coverage of the mesh on these types of convex shapes. This algorithm enables the detection of convex sections consisting of edge connections with discontinuous tangents, which cannot be judged from the curvature of the edges, and detection of the necessary sections after exclusion of the curved sections of the faces. Positioning mesh nodes over the detected convex section prevents loss of the connection elements, enabling generation of a mesh that reproduces the original shape, as shown in Fig. 13.

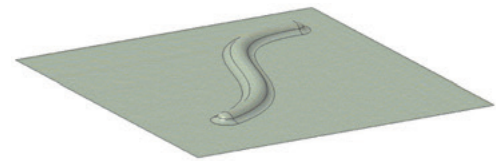


Fig. 5 Bead in CAD model

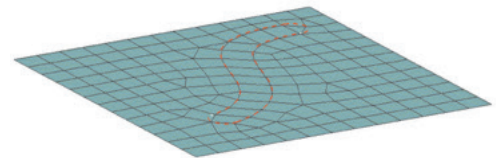


Fig. 6 Mesh generated by constraining edges only around the bead

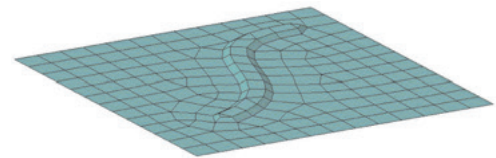


Fig. 7 Mesh generated by constraining all edges of the bead

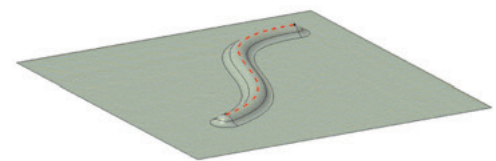


Fig. 8 Extracted ridge curve of the bead

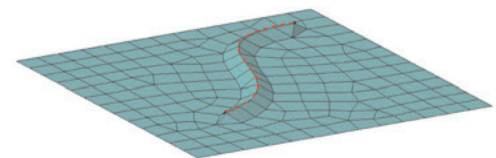


Fig. 9 Mesh generated by constraining ridge curve

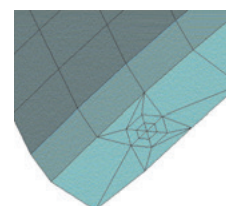


Fig. 10 Spot weld represented as hexagonal mesh pattern

5.5. Increased Element Quality

Constraint edges are programmed to increase the level of reproducibility of CAD shapes in the mesh, but when these edges are in close proximity it is difficult to generate uniform elements, and element quality declines. The new mesher detects elements that do not satisfy quality standards and either moves the nodes to the optimum position or removes them in order to increase the quality of the elements. As Fig. 14 shows, this process enables the achievement of a balance between highly detailed reproduction of shapes and element quality.

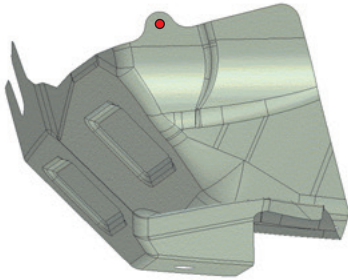


Fig. 11 Spot weld on convex flange

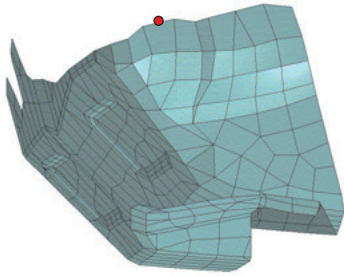


Fig. 12 Lack of elements at convex flange

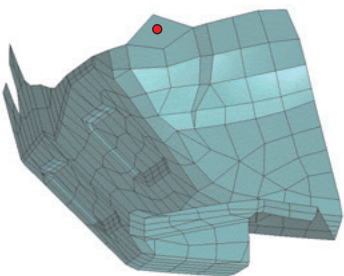


Fig. 13 Convex flange represented as mesh

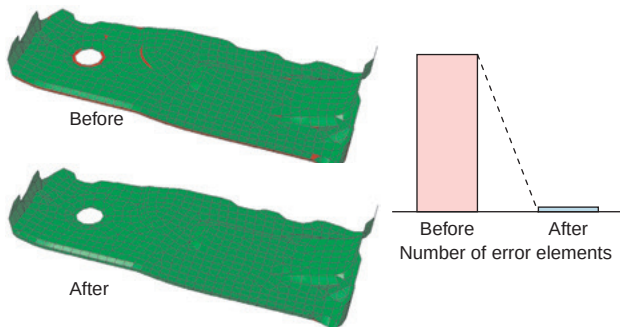


Fig. 14 Mesh refinement

6. Application of New System

The new system was used to generate the FE models used in an NV analysis. Figure 15 shows the man hours expended on model data registration and mesh generation, showing a reduction of approximately 80% against the conventional method. Figure 16 shows the results of the analysis using the models formulated by this system. The results are equivalent to those using the models formulated by the conventional method, and demonstrate that no calculation accuracy issues will be encountered in relation to models formulated by this system.

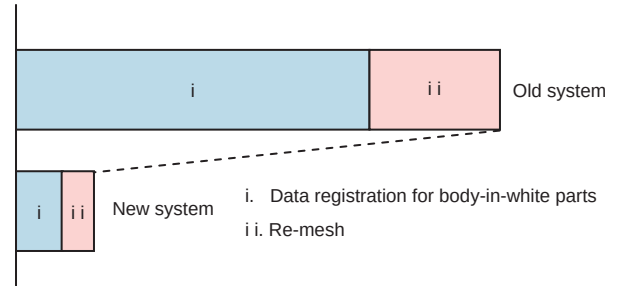


Fig. 15 Man-hour comparison

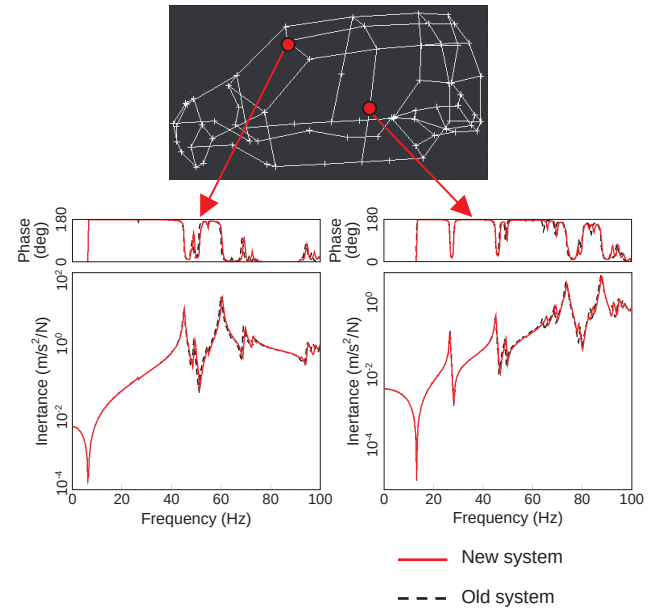


Fig. 16 Comparison of frequency response spectrum

7. Conclusion

- (1) Linking the model management system to the DPM has enabled the automated collection of parts data.
- (2) Procedures to increase the level of reproducibility in the mesh and enhance mesh quality, formerly conducted manually, have been automated.
- (3) The development of this model management system and an automatic mesher has reduced the man hours required for the generation of body-in-white FE models by approximately 80%.

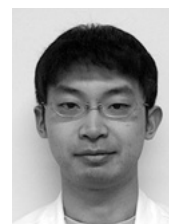
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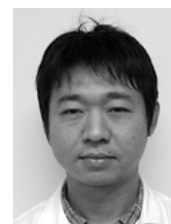
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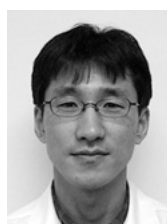
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