

Development of New Pre-processor for Car Body Analysis

Fumio NAKANO*

Atsushi IWAMOTO*

Kenji TAKADA*

Norikazu MATSUURA*

ABSTRACT

A new pre-processor was developed to shorten the finite element modeling process while improving calculation accuracy for car body analysis. The new pre-processor made it possible to create high quality models efficiently in a short time regardless of the skills and experience of the modeler. This was achieved by automatically identifying and correcting penetration and intersection between elements after division of a body in white into shell elements, automatically analyzing and converting spotwelds and other connection data into finite element data, assigning accurate material properties, automatically adding mass and incorporating dummies and barriers by compiling a material property, parts and mass database. In addition, the pre-processor was also given simple shape modification functions allowing model changes to be made in a short time when investigating specifications.

1. Introduction

Recent demands on product development have intensified for the development of high performance and high quality products in a short time. As one means for achieving this, designs can now be verified using detailed digital mockups created from three-dimensional CAD data. The development of automatic finite element generation algorithms⁽¹⁾⁻⁽³⁾ from these digital mockups has also made it possible to construct car body finite elements models in a short time without simplifying the CAD data or increasing the accuracy for finite element generation. However, demands for improved calculation accuracy and improvements in computer performance have also resulted in increasing model size and detail⁽⁴⁾, so calculation model quality as typified by the following items that have a large effect on calculation accuracy has become an issue.

- (1) Initial penetration between elements (components)
- (2) Element shape quality around spot connections

Therefore, even if finite element generation is speeded up by automation, the man hours required for model correction increase, so models with a high calculation accuracy still take a long time to complete.

The modeling period must be shortened to respond to the need for shorter development periods. In addition, in order to minimize differences in calculation results between individual modelers, it has also become necessary to automate or simplify correction work, the addition of finite element data other than the body in white, mass distribution, and other tasks. This paper reports on the development of a new pre-processor for car body analysis that deals with these issues.

2. Analysis Flow

Finite element analysis divides data into elements often called a mesh. The body in white mesh for performing car body analysis is currently created from three-dimensional CAD data using an in-house automatic mesh generator. The mesh data for a single car body is generated by this automatic mesh generator software in the same format as the parts structure tree. This data is managed together with the connection data (for example, spot welding, metal inert gas welding and other connection methods, connection positions) (Fig. 1), and a different model is automatically created for each crash analysis, vibration analysis or other analysis type.

* Tochigi R&D Center

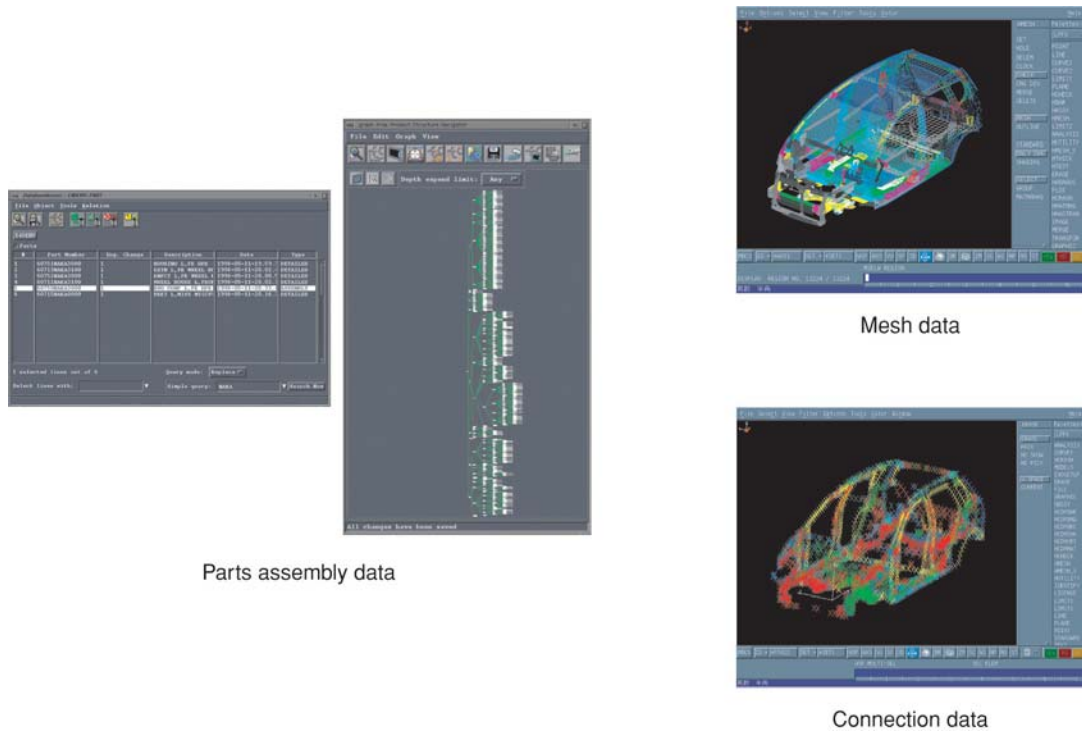


Fig. 1 In-house mesh generator

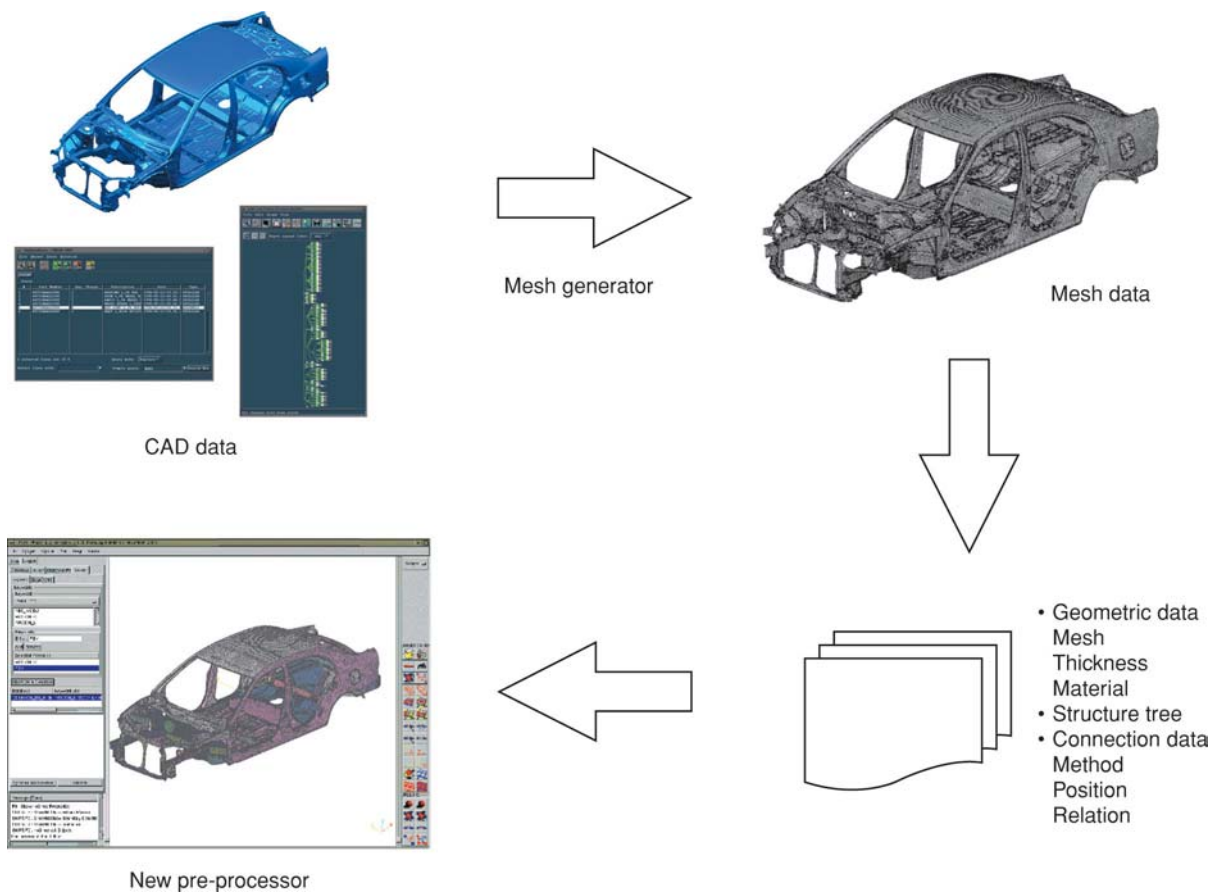


Fig. 2 Mesh data flow

Functions were developed for the new pre-processor to allow the following series of car body analysis modeling operations to be performed on models created by the automatic mesh generator in an extremely short time.

- (1) Loading of finite element data and connection data
- (2) Correction of initial penetration between elements
- (3) Automatic generation and correction of connection elements
- (4) Material property settings
- (5) Component connections other than the body in white
- (6) Mass setting
- (7) Boundary conditions

This paper introduces items (1) to (6) which help to greatly reduce the model creation period, and the shape modification functions that are needed when investigating specifications.

3. New Pre-processor Functions

3.1. Loading of Finite Element Data and Connection Data

First, the mesh data (nodes, elements, plate thickness, materials) for each body in white component created by the automatic mesh generator, the connection data (connection method, position, connected component names) and the parts configuration are loaded. (Fig. 2)

3.2 Correction of Initial Penetration

When performing crash analysis, if elements penetrate or intersect in the initial state before deformation, reaction force is generated at that point and affects the calculation accuracy, so this must be eliminated as much as possible. However,

even if there is no penetration in the three-dimensional CAD data that is the basis for finite element generation, penetration may occur in the mesh data due to the problems of the curvature of curved surfaces and the element size. (Fig. 3) Therefore, the new pre-processor simplifies correction of initial penetration by performing the following four steps in order. (Fig. 4)

- (1) Automatic correction of intersection
- (2) Displaying the direction of correction for intersecting nodes, and automatic correction after confirmation by the modeler
- (3) Direct movement of intersecting nodes by mouse operations
- (4) Automatic correction of interference

Case studies have shown that approximately 50% of intersecting portions are corrected by step (1), approximately 20% by step (2), and the remaining approximately 30% by step (3).

Using these functions makes it possible to perform work that formerly took approximately ten days in a single day or less.

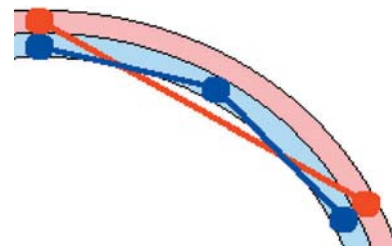


Fig. 3 Initial penetration by difference of mesh size

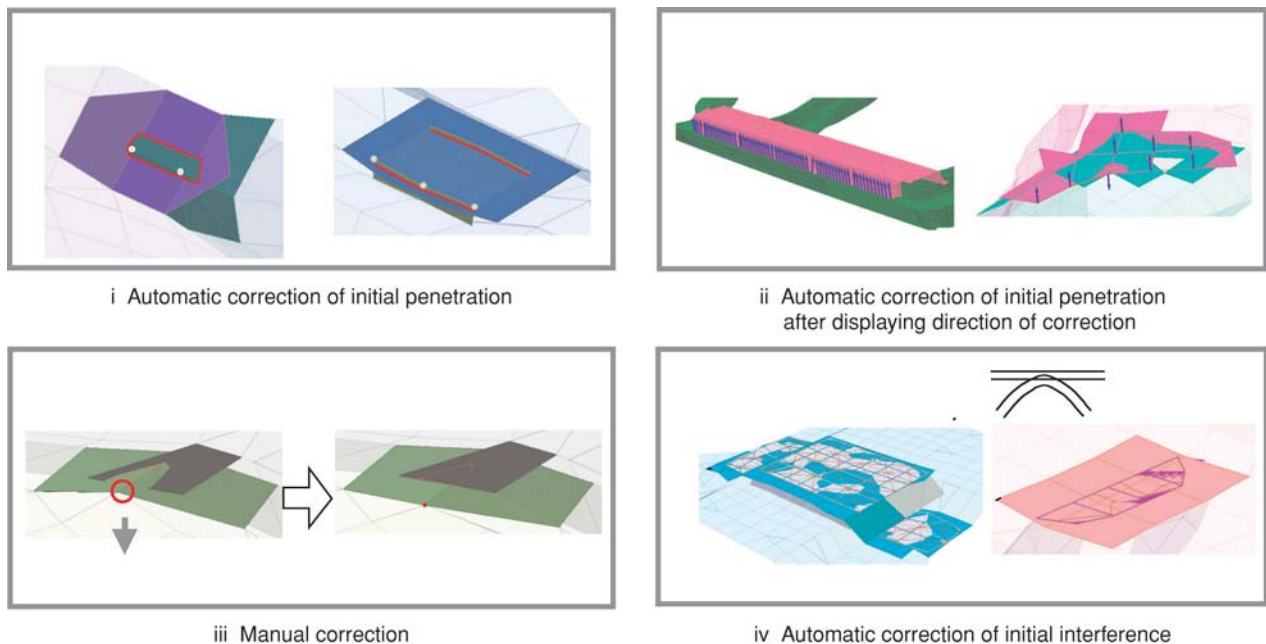


Fig. 4 Correction of initial penetration and interference

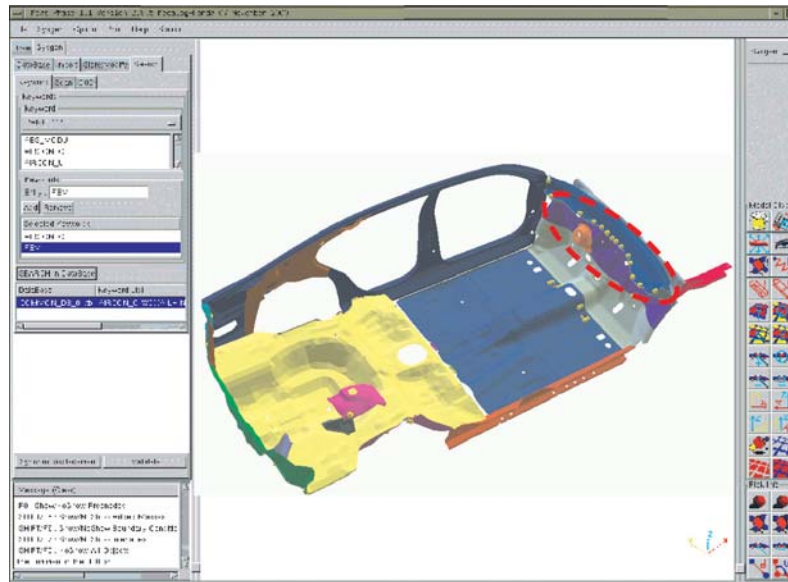


Fig. 5 Display of bad geometric data spots

3.3. Definition of Connection Elements

The spot welding, metal inert gas welding, bolt connection, hemming and glue elements are automatically defined using the connection data loaded in section 3.1. Current crash analysis programs use a spot data definition method like that of RADIOSS contact type 2 (INTERFACE TYPE2)^{(5), (6)} which does not use nodes to configure elements in spot positions. However, in this case the calculations sometimes end in error when projection cannot be performed normally from the spot position to neighboring elements. The new pre-processor was given functions to display these spot data (Fig. 5), modify the data (Fig. 6), and create simple spot data (Fig. 7). In addition, functions for creating other spot models such as spot models for strength and stiffness analysis (Fig. 8) were also added to support applications other than crash analysis.

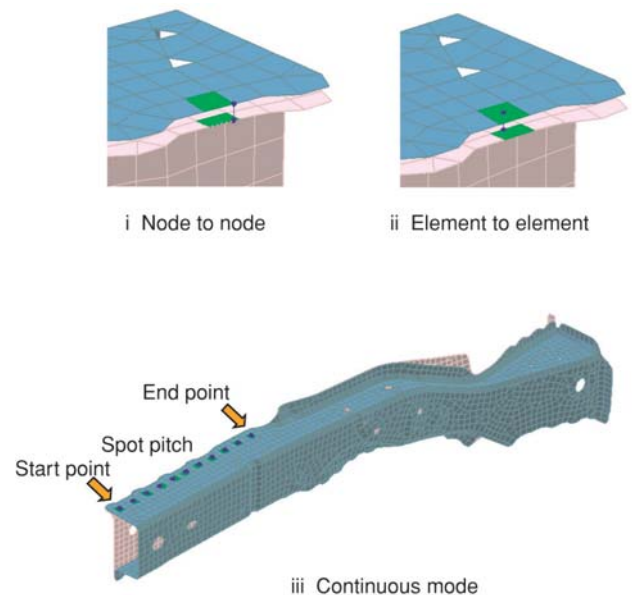


Fig. 7 Function of spot data creation

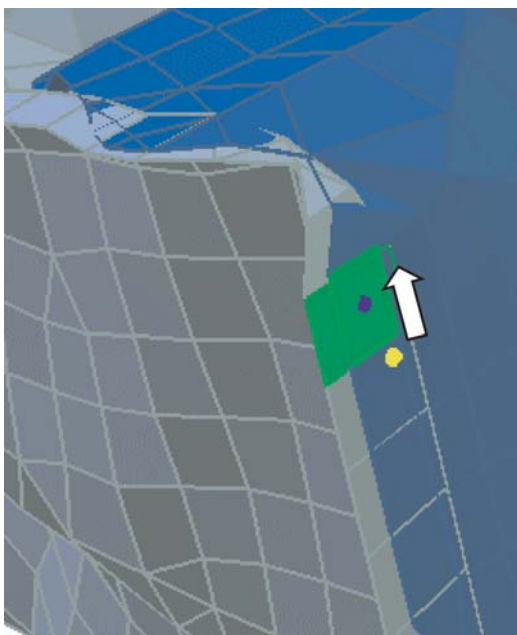


Fig. 6 Modification of spot data

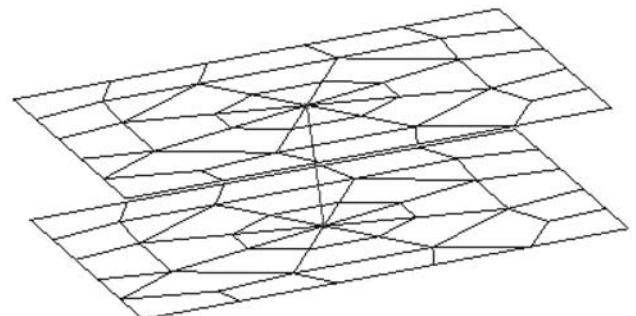


Fig. 8 Spot data for strength analysis

3.4. Material Property, Parts and Mass Databases

Improving the reproducibility of finite element models is an extremely important item for improving the accuracy of finite element analysis and detailed investigation of results in the future. The key points for this are thought to be as follows.

- (1) Accurately setting material properties
- (2) Modeling and setting parts
- (3) Setting mass data

3.4.1. Material property database

When analyzing nonlinear problems, the stress-strain curve of the materials must of course be set as accurately as possible. Furthermore, when performing crash analysis the dependence of the yield stress on the strain rate must also be taken into consideration.

Automobiles are comprised of an extremely large number of different materials. Thus far it had been extremely difficult to set these values accurately, and this had adversely affected the calculation accuracy. Therefore, a material property database was compiled, and the new pre-processor first loads the material property names noted in the mesh data, and then automatically sets the correct stress-strain curve.

In addition, a function was also provided to allow modelers to access the database and select the optimum values when changing the material property specifications.

3.4.2. Parts and mass databases

The handling of parts other than the body in white will be an extremely important factor for finite element analysis in the future. For example, the parts reproducibility affects both improvement in the calculation accuracy for the high frequency regions during vibration analysis, and also improvement in the deformation amount and acceleration

accuracy during crash analysis.

The current issue is that creating the finite element models for the necessary parts requires approximately the same number of elements and creation time as for the body in white.

However, the body in white creation time has been shortened by the automatic mesh generator. Therefore, the parts models must also be created by the time the body in white is completed. In addition, when connecting the parts, if the connection methods and correction of intersection are not also automated, the analysis period cannot be shortened.

On the other hand, when the desire to change the specifications arises after the required parts have been set in the body in white and analysis has been performed, work to replace parts is necessary. When parts that have been set are removed and the setting work is performed again using a general-purpose pre-processor, errors often occur in the original finite element data. In particular, models targeted by the new pre-processor are comprised of numerous parts and connection data, and replacing even a single part makes it necessary to accurately delete all the connection data, mass data, boundary conditions and other data related to that part.

Therefore, parts and mass databases that include data managing functions were developed for the new pre-processor in order to solve the above issues. (Fig. 9)

Parts other than the body in white are registered as parts modeled with finite elements or other models and parts not so modeled. However, the part name, part number, destination, analysis type and other key words are added during registration so that anyone can reliably search for the target part. This has also proven effective when searching for common parts for other models.

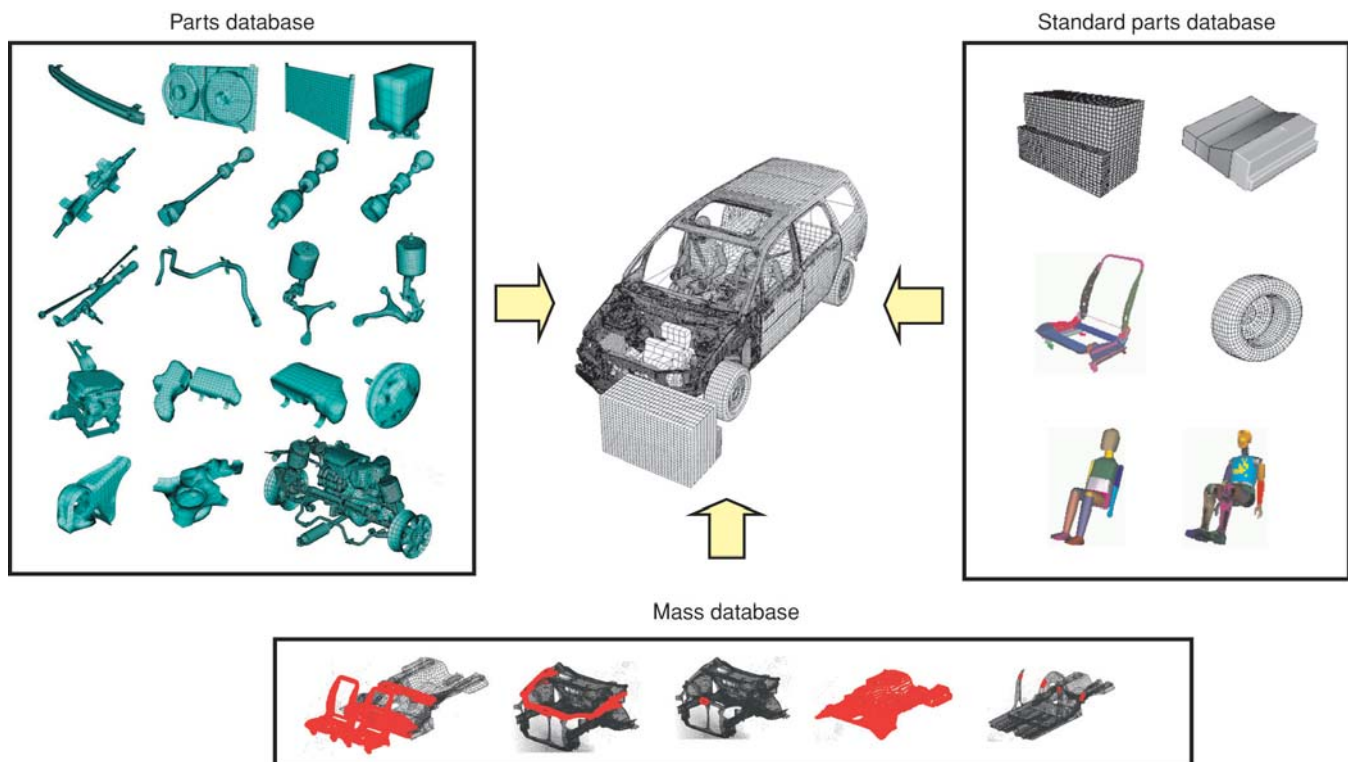


Fig. 9 Parts and mass databases

When attaching parts stored in the parts database to the body in white, the necessary template is set for each analysis type. This makes it possible for even beginners to accurately attach parts by following the steps below, and also prevents parts omissions. (Fig. 10)

- (1) Setting the position
- (2) Checking for and correcting penetration
- (3) Connection to the body in white

There is also a function that searches for and displays parts near the connection position. This allows connection work to be performed even if the name or other information regarding the other part to be connected is not known. Also,

connected and unconnected locations are indicated with different colors for each connection type, allowing easy checking of connection omissions.

The registered mass data can be automatically distributed to parts requiring added mass using a template similar to that of the parts database. (Fig. 11)

In addition, normally the mass and longitudinal balance of the completed finite element model and the actual vehicle do not match, so a function was also developed for automatically adding mass to achieve the target mass and longitudinal balance. (Fig. 12)

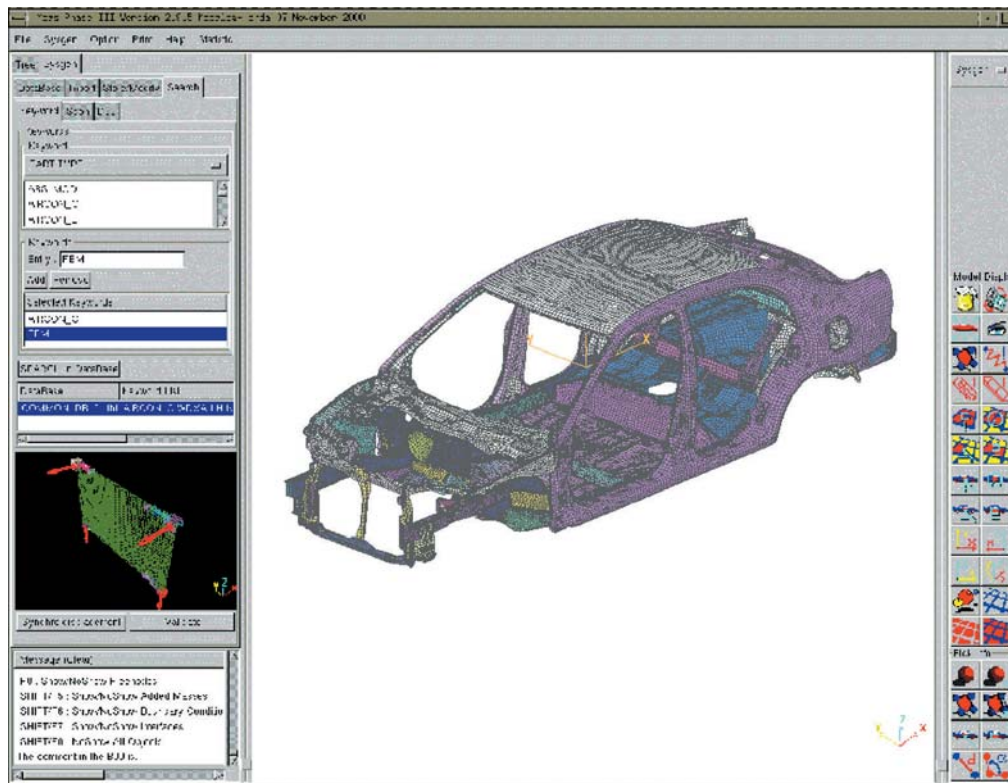


Fig. 10 Menu for automatic connection from parts database

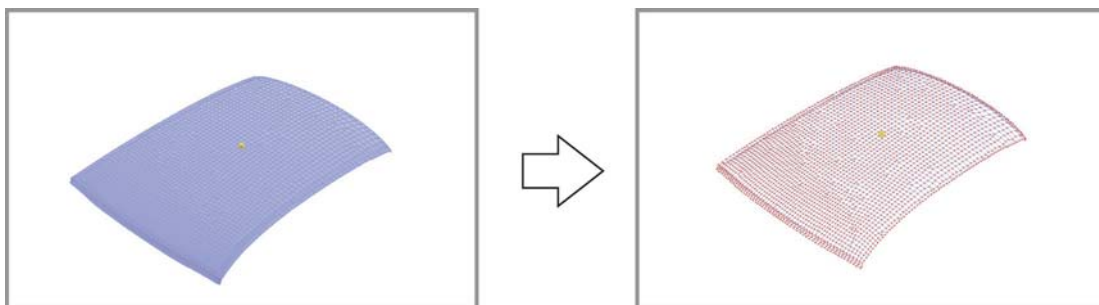


Fig. 11 Automatic mass distribution

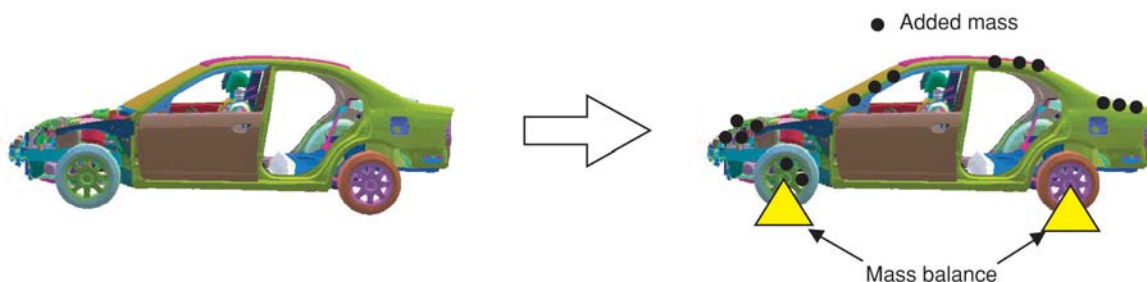


Fig. 12 Automatic mass distribution

3.5. Simple Shape Modification Function

When modifying the finite element model shape, the ideal method is to modify the shape at the CAD data and then generate the mesh again. However, in this case work to correct initial intersection, set conditions for connection, and set parts must be repeated each time the shape is changed. Therefore, the following functions were developed to allow simple shape modification using the created finite element

model in order to reduce the analysis man hours when investigating different proposals. (Fig. 13)

- (1) Section shape modification
- (2) Extension
- (3) Section scaling
- (4) Rotation and translation
- (5) Symmetrical copy
- (6) Mesh creation by node offset

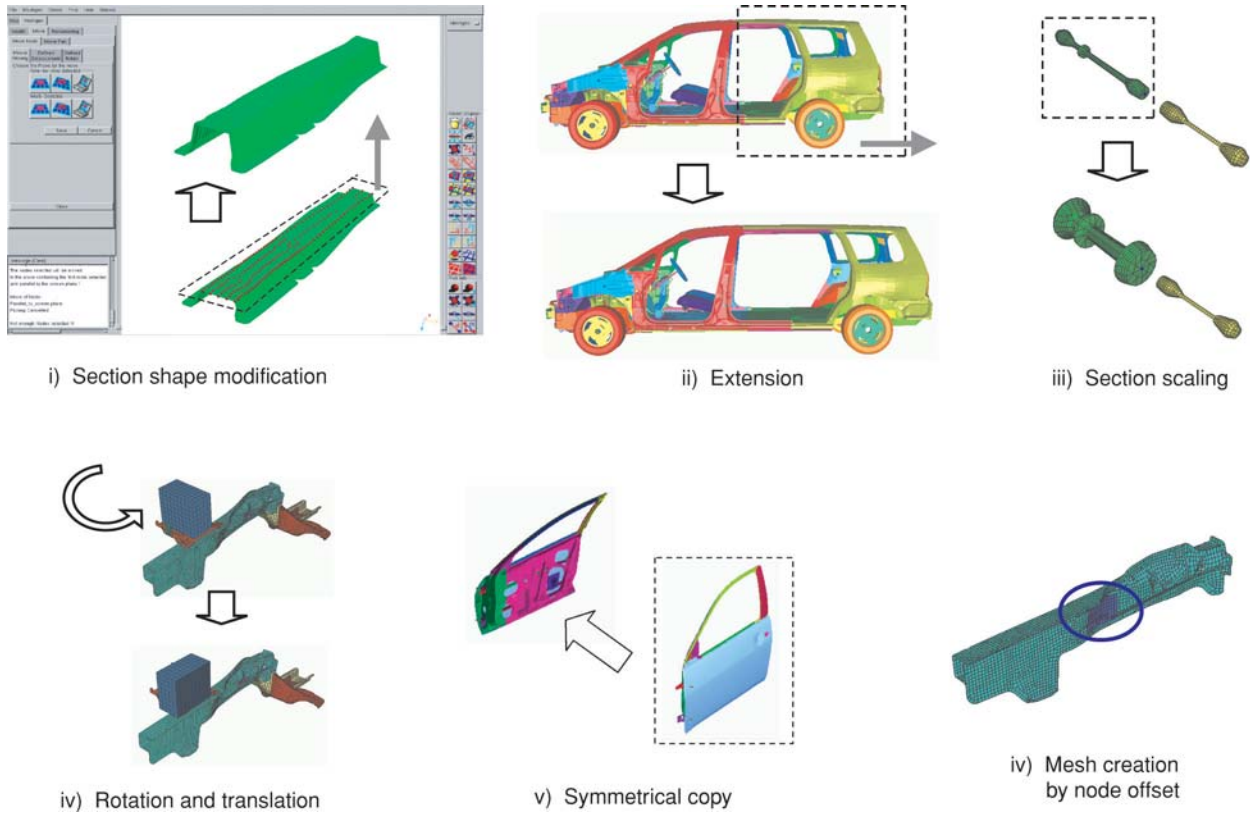
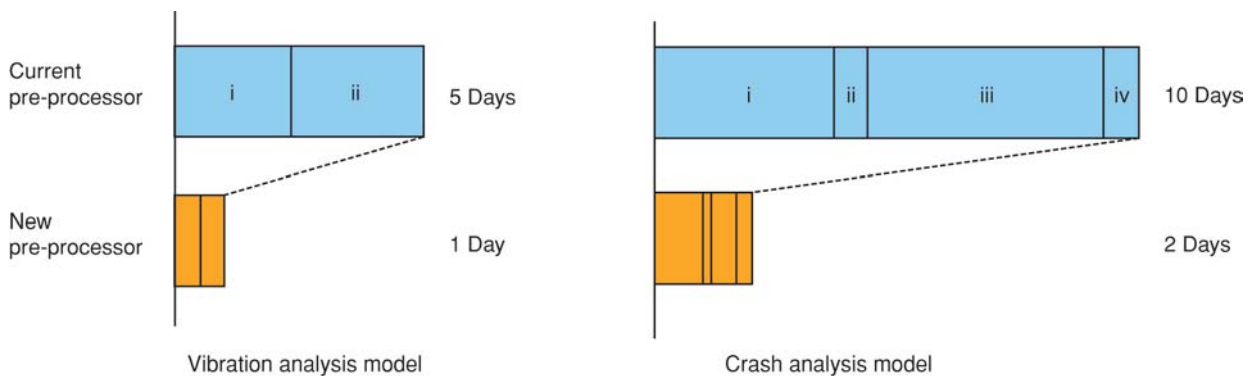


Fig. 13 Mesh data modification



- i Correction of initial penetration and interference
- ii Creation and modification of connection data
- iii Adding other mesh data and mass
- iv Creation of initial conditions and boundary conditions

Fig. 14 Modeling period

4. Application Examples

Actual examples of models created using the new pre-processor are introduced below.

Fig. 14 compares the modeling periods with the current method, and Fig. 15 compares the calculation results with test results. These examples show that the modeling period is reduced compared to the current modeling method, and the calculation accuracy is also excellent.

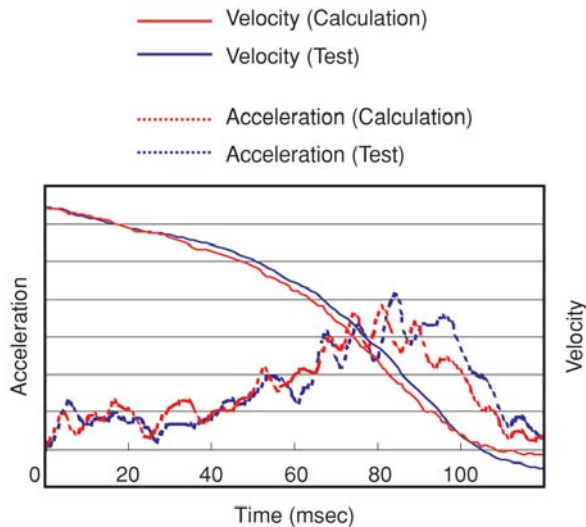


Fig. 15 Acceleration and velocity of floor in frontal offset crash

5. Conclusion

Use of the aforementioned initial penetration automatic correction function, analysis-specific connection model automatic creation function, and material property, parts and mass databases enabled the following.

- (1) Calculation conditions could be added in two days after completion of the body in white model by the automatic mesh generator.
- (2) Even less experienced engineers could perform the analysis operations that are currently performed by specialists.
- (3) Specifications could be changed easily and swiftly.

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■ Authors ■



Fumio NAKANO



Atsushi IWAMOTO



Kenji TAKADA



Norikazu MATSUURA