

Development of CAE Technology Applicable to the Concept Stage of BIW

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ABSTRACT

A CAE technology was developed which can be applied to the BIW concept stage in the design of lightweight, high-performance vehicle bodies. This technology utilizes a parametric FE model formulated from design lines and frame cross-sections, and enables analysis of body performance for static, dynamic and side impact characteristics. Because this technology does not require CAD drawings, designers can quickly evaluate numerous ideas in FE models, enabling the creation of new frame structures. Comparison of analysis results with conventional high-accuracy large-scale models has confirmed correlation between the methods, and verified that it is possible to predict performance from the concept stage of BIW using the new technology. This paper discusses the application of CAE at the concept stage of BIW to examine frame structure and predict performance when altering the design of a vehicle.

1. Introduction

As a part of the continuing effort to address automotive environmental issues, there has been a demand for technology to decrease the weight of the BIW (body in white) while not reducing safety or marketability. CAE (computer aided engineering), which is a core technology in the development of a lightweight BIW, together with improved computer performance, makes it possible to predict performance more accurately. However, the current CAE process is mainly focused on CAD (computer aided design) drawing based FE (finite element) models, and at the concept stage of BIW (stage at which there are no CAD drawings), performance evaluation of the frame structures being considered by the designer cannot be carried out in a short period of time. This paper reports on the newly developed FE model creation technology that does not require CAD drawings^{(1), (2)}, and on CAE technology that enables quick evaluation of frame static, dynamic and collision performance characteristics, using the FE model created with the new method.

2. Overview of Concept Stage CAE Technology

2.1. Timing of CAE Application in Vehicle Development

Conventionally, CAE has been applied after CAD drawing creation, at the stage of making vehicle performance predictions. The CAE method proposed in this paper is suitable for the BIW concept stage, as shown in Fig. 1. This stage is the period from design sketch through the creation of clay models. The aim is to incorporate a lightweight and high-performance frame structure into the styling design. During this period, it is possible to propose lightweight and high-performance frame structures, by predicting body characteristics and taking countermeasures. However, because there are frequent design changes during this period, it is very important to make model corrections and to rapidly carry out characteristics predictions. The goal of this technology was therefore to determine the direction of the design, rather than analysis accuracy.

There are two types of vehicle development flow; new model vehicle development, and existing model carryover.

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- (1) In the case of new model vehicle development, a new frame structure study is carried out, and the frame structure of an existing vehicle is not available to be used. From when the sketches are started, CAE is applied and many frame structures are proposed, that can be lightweight and high-performance.
- (2) In the case of an existing vehicle carry-over, performance changes that accompany upper body styling changes are predicted by the CAE technology proposed in this paper, and countermeasure proposals are made. The requirement is to propose the most effective countermeasure spec within the existing layout.

In both development flows (1) and (2), as shown in Fig. 1, the application of concept stage CAE technology proposed in this paper makes development of lightweight, high-performance frame structures possible.

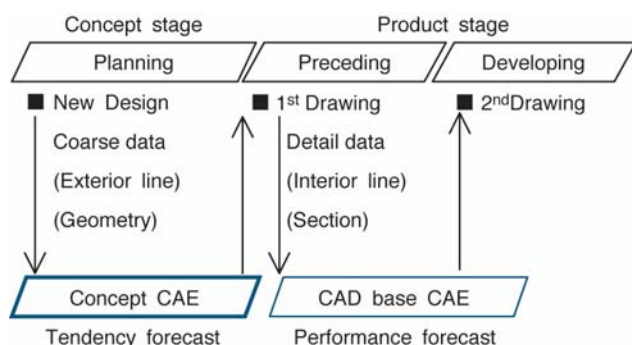


Fig. 1 Car development flow & CAE

In addition, after the design has been determined and CAD drawings issued, the application of conventional, large-scale CAE technology based on CAD drawings is used for NV (noise vibration), stiffness and impact performance predictions.

2.2. Modeling Concept

With conventional CAE, detailed FE models are necessary for vehicle performance predictions. The part shapes are created with CAD drawings, and the detailed, large-scale FE model is created using FEM (finite element method) pre-processors. Highly accurate analysis is expected of detailed, large-scale models. However, because CAD drawings are used, much time is needed for modifications, depending on the area of change, or the shape.

In contrast, with the parametric geometry model used in this project, it is expected that a simplified FE model will be able to deal with spec studied for frame structure proposals, in a short period of time. The simplified FE model is created using the drawing-free modeling technology proposed in this paper, utilizing design data and section shape data. This model can quickly respond to model changes that accompany frame structure and design studies without the creation of CAD drawings and is suitable to frame structure studies.

2.3. Drawing-free Modeling Technology

Figure 2 shows the model creation flow utilizing the drawing-free modeling technology.

- Establishing the body frame member layout, from design shapes
- Establish cross-sections on frame layout lines
- Create beam elements

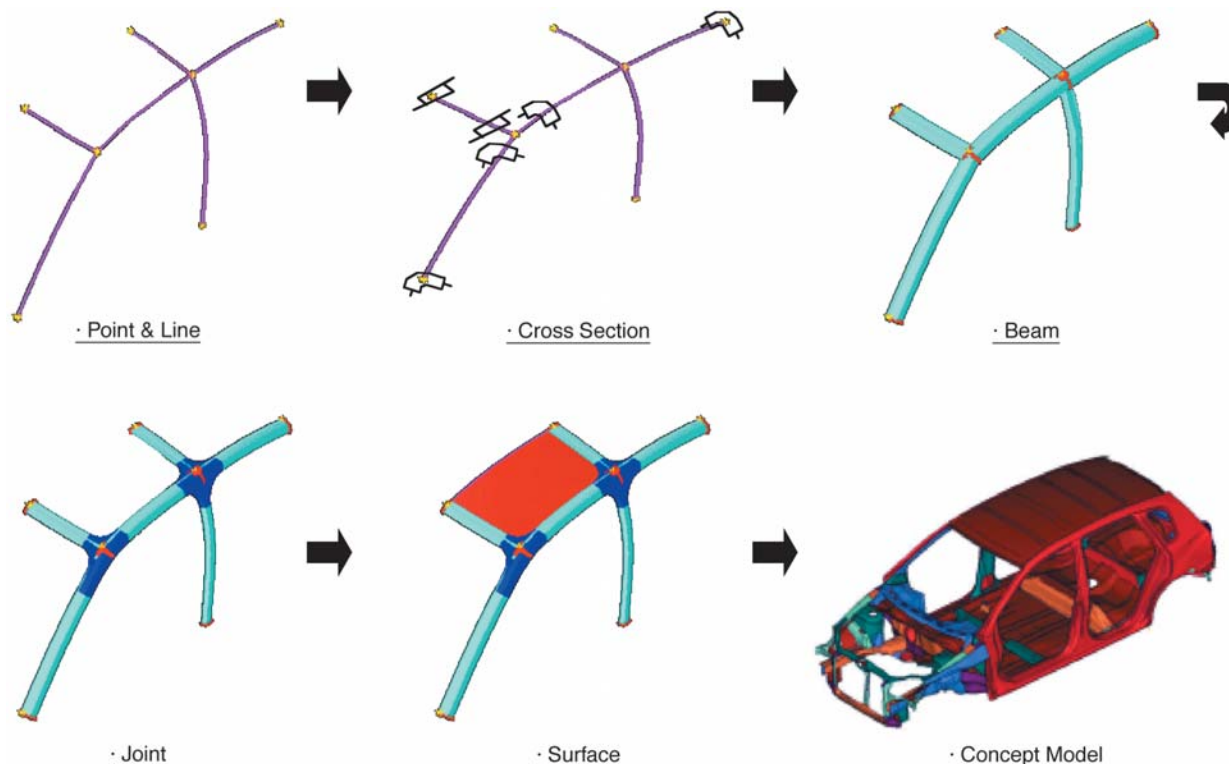


Fig. 2 Concept modeling flow for body structure

- Create joint elements in connection areas where multiple beam elements come together
- Create surface elements between frames

By repeating the work outlined above, it is possible to create a frame model for the whole body (referred to as the concept model hereafter) without creating CAD drawings.

2.4. Parametric Technology

With the concept model, it is possible to change the shape or structure at will. As shown in Fig. 3, if overall height dimensions are input, changing the design of the base concept model, then it is changed to a new model. It is possible to implement body performance prediction analysis in a short period, if the frame layout or section shape changes. In the case of a topology change, if the changed part only is newly created, it is possible to immediately apply parametric technology. Utilizing drawing-free modeling and parametric technology, a new method has been actualized that creates frame structure models without the making of CAD drawings. This enables quick checks of the effect of design changes, making it possible to study structure spec differences within a short period of time.

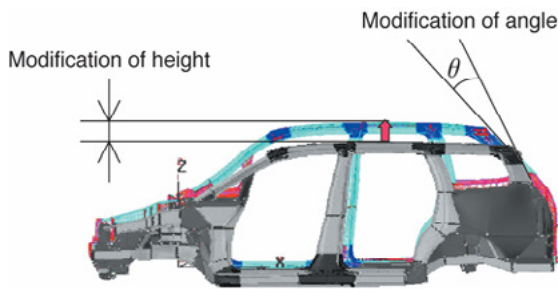


Fig. 3 Model modification using parametric technique

3. Verification of Concept Modeling

Using the analysis model created through the use of the drawing-free modeling and parametric technology, BIW performance evaluation is implemented. In this example, a verification of the concept model was carried out, by comparing it with a conventional detailed model, concerning side impact performance and body stiffness (dynamic, static).

3.1. Time Required for Model Creation

Figure 4 shows the hours taken to create a model with a modification to the concept model pillar angle. In comparison with the conventional method, there was a large reduction in the time taken when utilizing parametric technology. When implementing a frame structure study within a limited development period, it was confirmed that, in comparison with the CAD drawing based modeling technology, many more frame structure studies are possible.

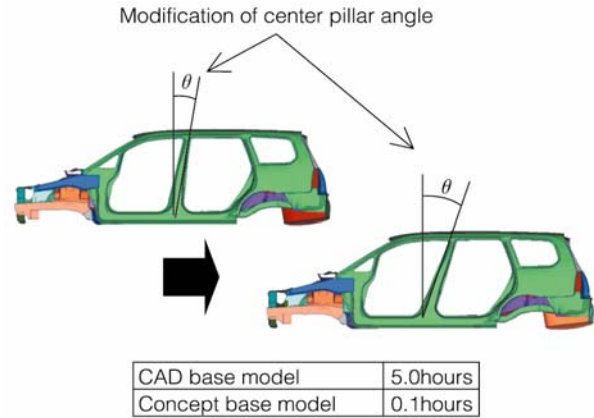


Fig. 4 Man-hour comparison for modeling

3.2. Verification of Impact Analysis

Carrying out side impact analysis using the concept model, verification was made of predictions of major deformation at impact. A comparison was made of the side impact analysis results using actual vehicle crash testing, CAD based FE models, and side impact analysis results using the concept model. When implementing the side impact analysis, a concept model was created for the body and door, and an existing model was used for the dummy and seat, etc. In order to judge the appropriateness of the analysis results, a comparison was made of three items – amount of center pillar penetration, center pillar penetration mode, and body reaction. The amount of center pillar deformation when the center pillar and the dummy come into contact is taken as the center pillar penetration amount, and the amount of deformation determined from the bend angle is the center pillar penetration mode.

Figure 5 shows the center pillar deformation results before and after side impact. Comparing the results of concept modeling and CAD drawing based modeling with results from an actual vehicle, there is good correlation between the amount of center pillar penetration and the amount of deformation determined from center pillar bend angle. Figure 6 shows the body reaction force. Comparing the body reaction force of the concept model and the CAD based model shows good correlation in reaction force values. Through these comparisons it was confirmed that by carrying out side impact analysis with a concept model it is possible to predict BIW performance.

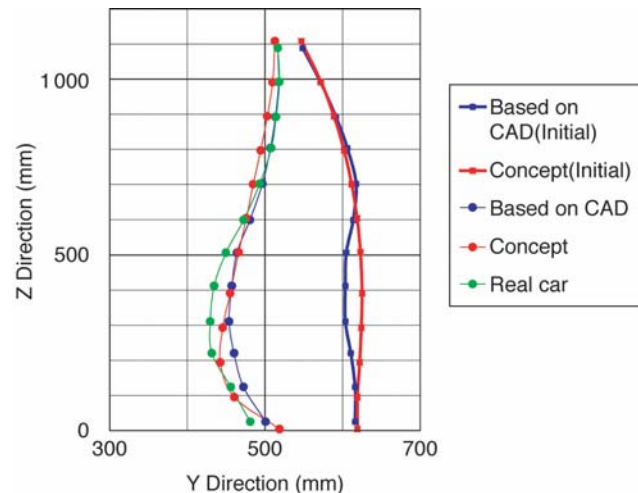


Fig. 5 Deformation of the center pillar in a side impact test and simulation results

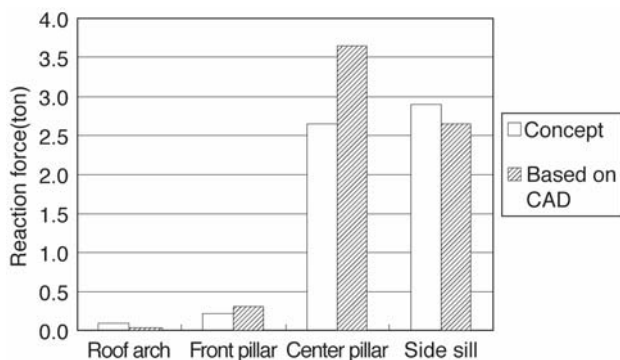


Fig. 6 Reaction force

3.3. Verification of Body Eigen Value Analysis

Carrying out eigen value analysis using the concept model, verification was made of frame characteristics predictions in the low order mode of 30 – 80 Hz. The focus on low order mode is due to the fact that its characteristics are determined by BIW. Things other than BIW, such as panel surface stiffness, etc, more often determine higher order mode characteristics.

In order to judge the appropriateness of the analysis results, eigen value analysis was carried out using the concept model and the CAD based model, and a comparison made of mode generation order and eigen value accuracy.

The results are given in Fig. 7. For both the concept model and the CAD based model, the mode generation order was the same – torsion, front lateral bending, bend, and shear bending. As for the eigen values, in comparison with the CAD based model, the concept model showed a tendency to be higher, and that difference was +14% maximum. Because the order of mode generation can be predicted, it was confirmed that it is possible to predict frame characteristics using the concept model.

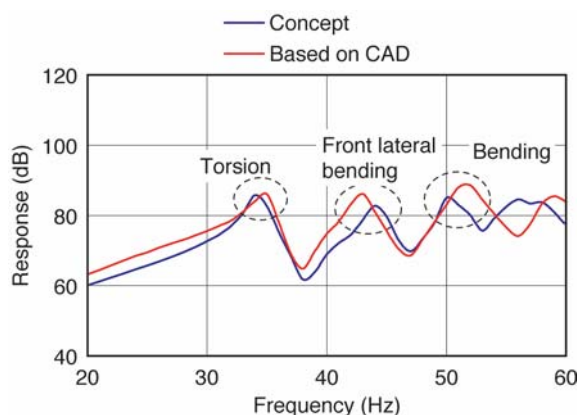


Fig. 7 Result of eigen value analysis

3.4. Verification through Body Static Stiffness Analysis

A comparison of bend and torsion body static stiffness was made, between values measured on the vehicle and values calculated from the CAD drawing based model and the concept model. The results are given in Fig. 8. For both bend and torsion stiffness, the concept model calculated values showed a tendency to be higher than the vehicle

measurements and the CAD drawing based model. As shown in Fig. 9, the CAD drawing based model more accurately expresses the vehicle shape, while in contrast the concept model intentionally simplifies the detail shape expression, so the calculated values become higher.

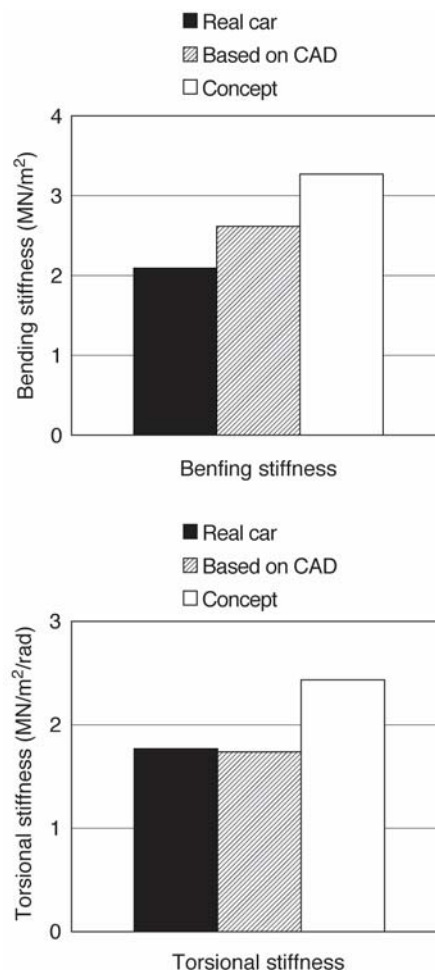


Fig. 8 Comparison of static stiffness with real car

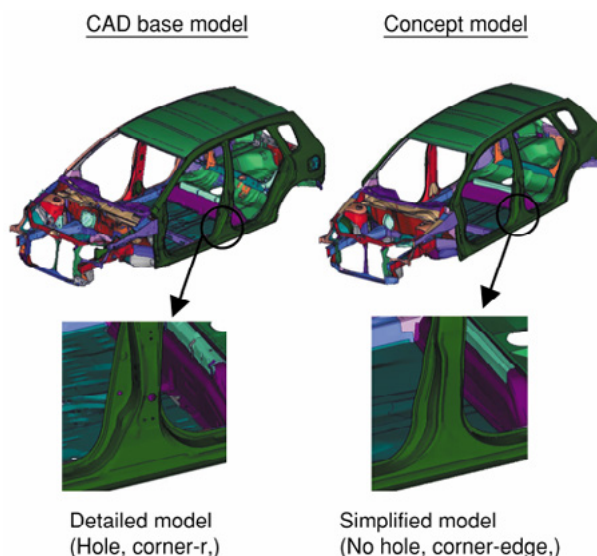


Fig. 9 Comparison of detailed CAD base model and concept model

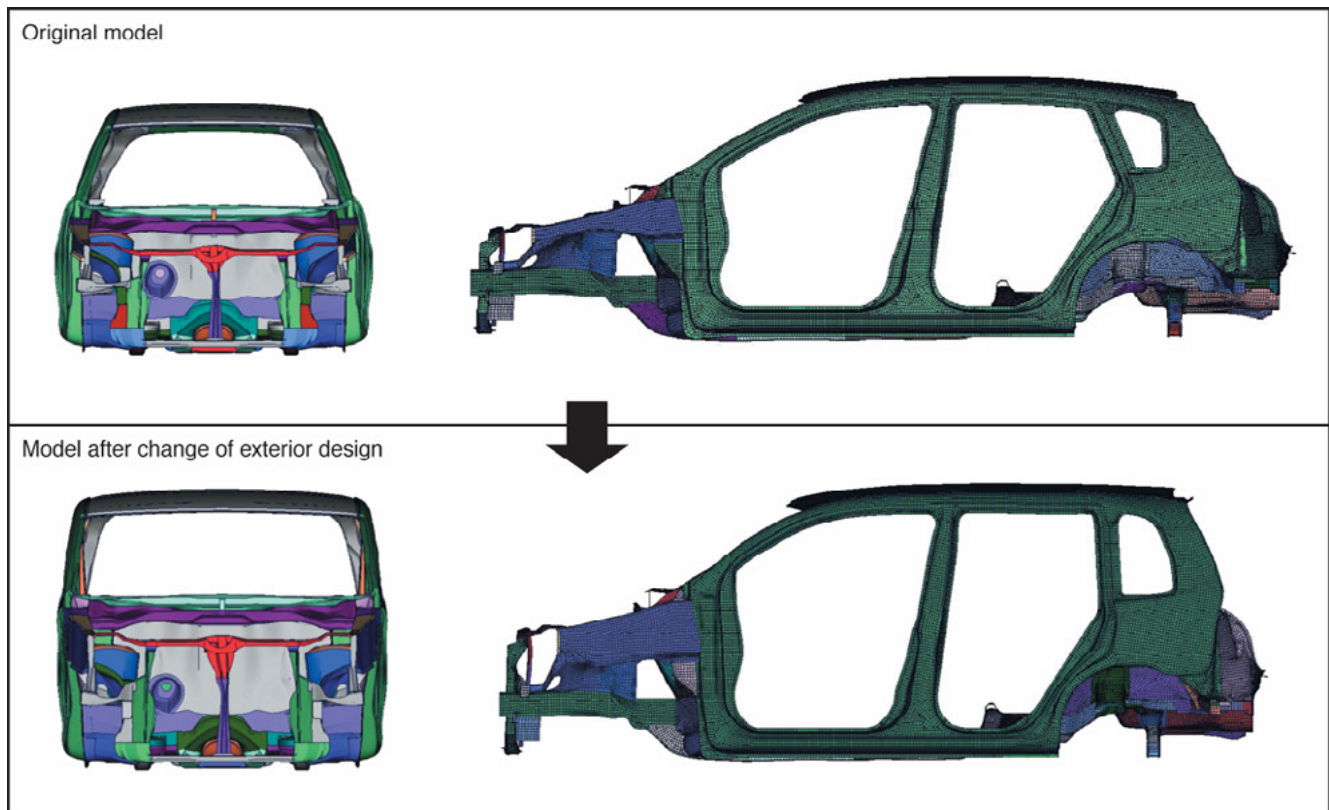


Fig. 10 Original model and model after change of exterior design

4. Examples of Application in Development

This technology was applied to a vehicle with a common BIW platform. A base model was created, using parametric technology then, the model is changed to incorporate the exterior design. The model incorporating external design is updated in a frame structure study model which reflects each pillar and side sill's section shape, fully considering the packaging. Figure 10 shows the original model and the model after the design changes. Figure 11 shows a comparison of section shapes, between the frame structure study model and the original model.

Using the three concept models above, a performance prediction analysis was carried out for side impact, eigen values and body stiffness. The effect of exterior design and section shape changes on BIW performance was determined.

	Fr pillar	Roof side rail	Center pillar	Side sill
Original model				
Section modified				

Fig. 11 Sections before and after modification

4.1. Application to Side Impact Analysis

Figure 12 shows the amount of center pillar penetration obtained through analysis, and Fig. 13 shows the

displacement amount determined from the center pillar penetration bend angle. Due to exterior design changes, the center pillar penetration amount increased, and the displacement amount determined from center pillar penetration bend angle increased. Due to section shape changes, the center pillar penetration amount further increased, and the displacement amount determined from center pillar penetration bend angle increased.

According to this model's side impact analysis results, the cause of the amount of center pillar penetration is estimated, a model is created that implements section changes, and analysis is carried out. These results are included in Fig. 12 and Fig. 13. Due to the countermeasures, in comparison with the original model, the amount of the center pillar penetration is reduced, and the displacement determined from center pillar penetration bend angle is increased. From the results, BIW performance against side impact is expected to be equivalent to the original vehicle, or better.

4.2. Application to Eigen Value Analysis

Next, the results of eigen value analysis are shown in Fig. 14. As for transmission characteristics, the rear floor frame end vertical response is shown for the original model and the frame structure study model.

From analysis results, it is expected that there will be a dramatic worsening of rear torsion mode in comparison with the original model, as shown in Fig. 15. As a result of making countermeasures, it was learned that improving tailgate opening stiffness is effective, and so a model was created with countermeasures to improve tailgate opening stiffness, and an eigen value analysis carried out. The results are shown in Fig. 16. It was confirmed that by making section changes, the rear torsion mode was improved to be equivalent to a vehicle having the original model platform.

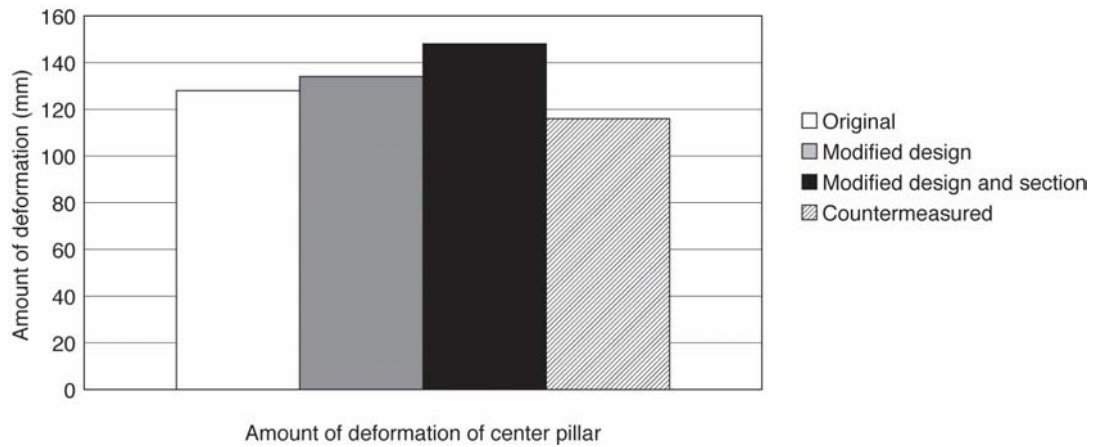


Fig. 12 Result of analysis of amount of deformation

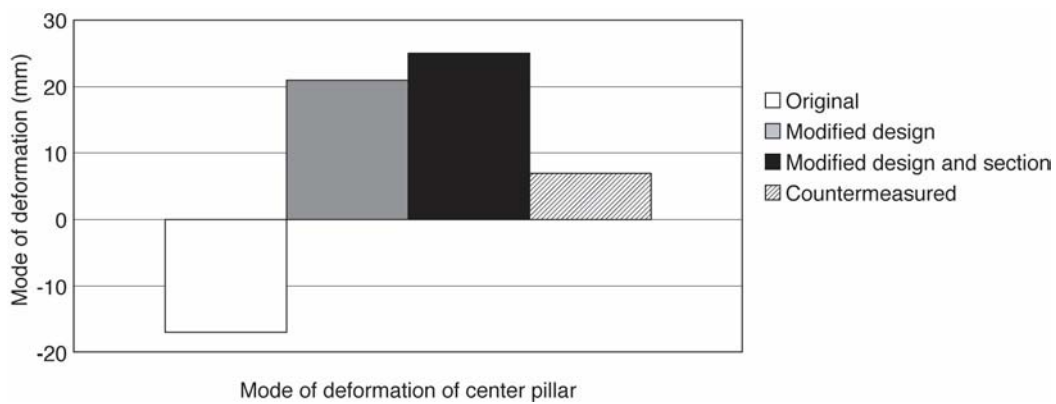


Fig. 13 Mode of deformation results

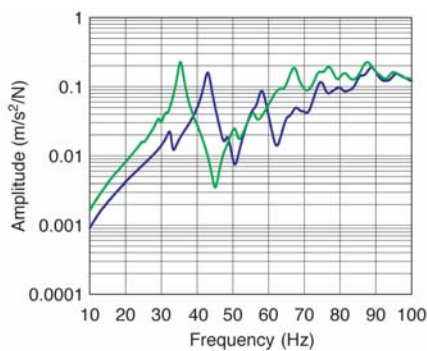


Fig. 14 Response of rear floor frame end

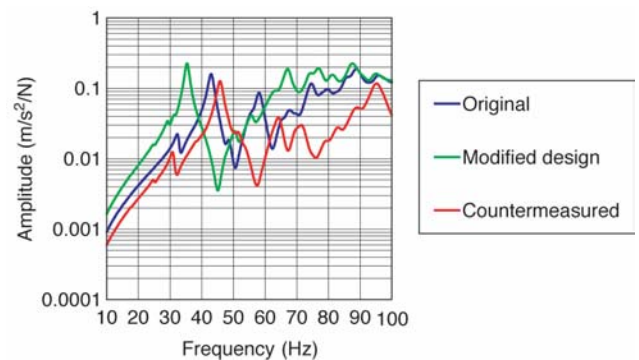


Fig. 16 Response of rear floor frame end after modification

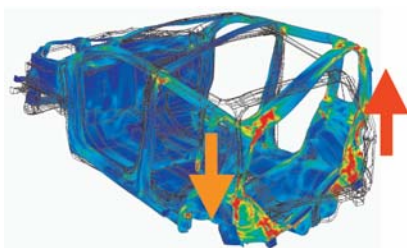
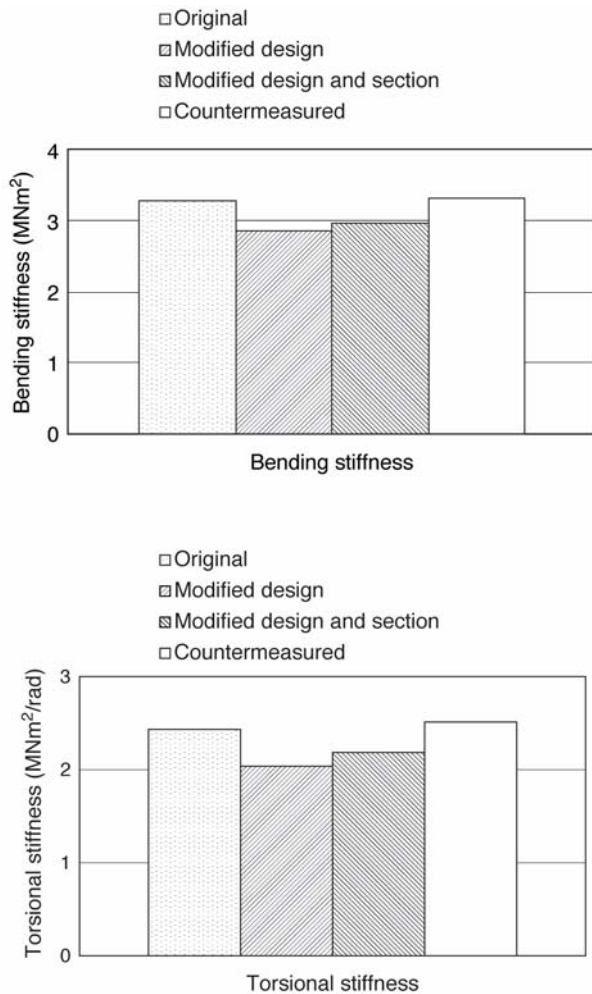


Fig. 15 Rear torsional mode

4.3. Application to Vehicle Static Stiffness Analysis

The static stiffness analysis results are given in Fig. 17. With the model incorporating exterior changes with respect to the original model, it was learned that both the bending and torsion were lower. Due to the section shape change and tailgate opening stiffness improvement countermeasures, it was confirmed that stiffness is improved and that it is equivalent to models with the original platform.



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Fig. 17 Static stiffness of concept models

5. Summary

The following results were obtained through the development of CAE technology that uses concept modeling.

- (1) Using drawing-free parametric model technology, it is possible to make CAE BIW performance predictions for side impact, eigen values, and stiffness, at the BIW concept stage before CAD drawings are created. A frame structure can then be made into a CAD drawing, having the performance predicted by CAE.
- (2) By applying structural analysis at the same time as design studies, it is possible to make repeated performance analyses, with a variety of frame structure proposals concerning BIW structures which greatly affect vehicle development, leading to the appropriate frame structure.

References

- (1) Zimmer, H., Hovelmann, A., Schmidt, H., Umlauf, U., Frodl, B., Hanle, U.: Concept development tool Flexible generation of parametric virtual Prototypes in car body design, VDI Report Nr. 1559-2000

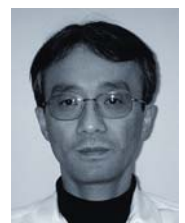
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